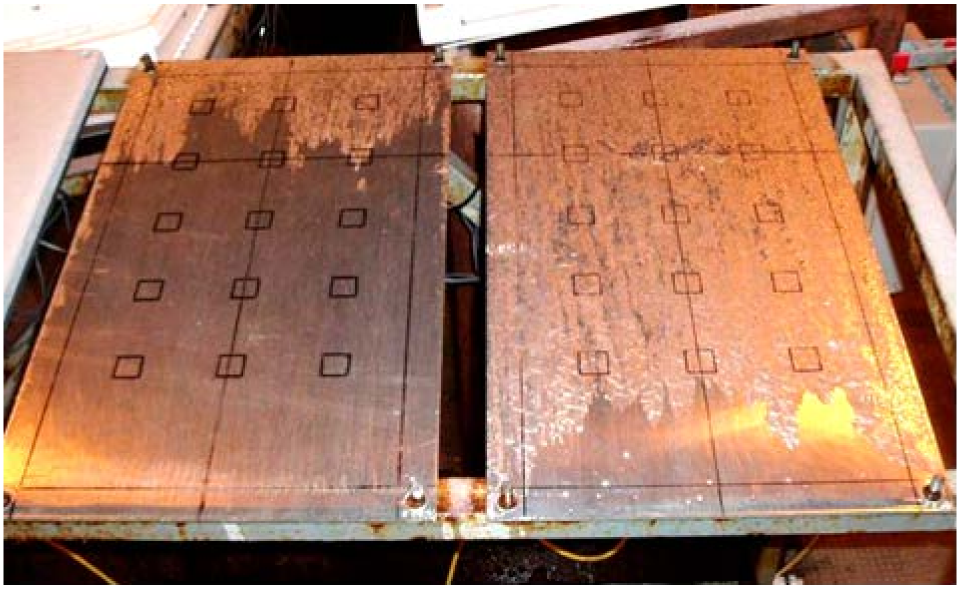
TP 14447E

Effect of Heat on Endurance Times of Anti-Icing Fluids



Prepared by

Prepared for
Transportation Development Centre

In cooperation with

Civil Aviation
Transport Canada

And

The Federal Aviation Administration
William J. Hughes Technical Center

October 2005
Final Version 1.0

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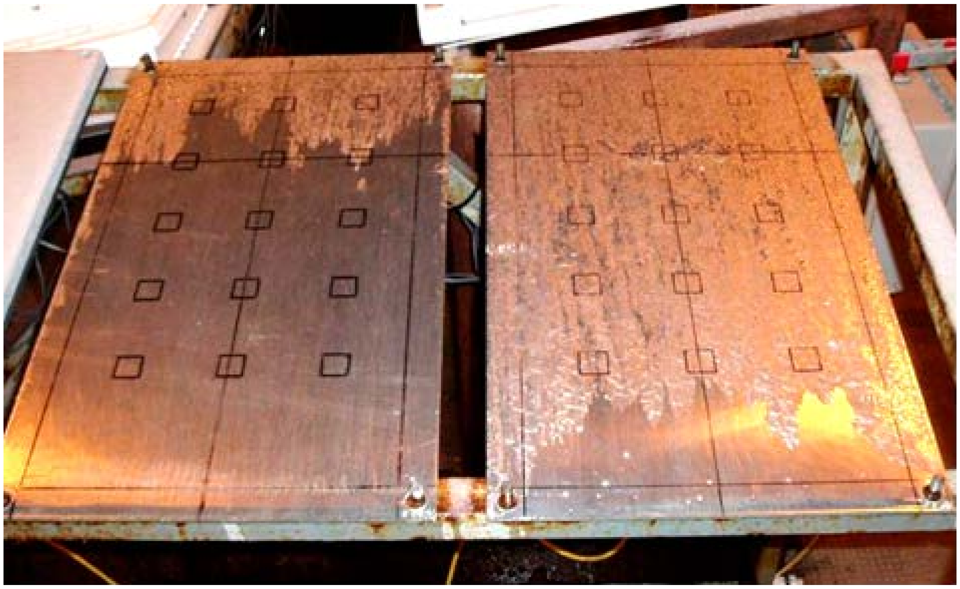

by

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October 2005
Final Version 1.0

DOCUMENT ORIGIN AND APPROVAL RECORD

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Un sommaire français se trouve avant la table des matières.

*This report was first provided to Transport Canada as Final Draft 1.0 in October 2005.
It has been published as Final Version 1.0 in July 2018.*

***Final Draft 1.0 of this report was signed and provided to Transport Canada in October 2005. A Transport Canada technical and editorial review was subsequently completed and the report was finalized in July 2018; Nicoara Moc and Jean Valiquette were not available to participate in the final review or to sign the current version of the report.*

PREFACE

Under contract to the Transportation Development Centre of Transport Canada, APS Aviation Inc. (APS) has undertaken a research program to advance aircraft ground de/anti-icing technology. The specific objectives of the APS test program are the following:

- To develop holdover time data for all newly-qualified de/anti-icing fluids;
- To conduct endurance time tests in frost on various test surfaces;
- To assist with the operational evaluation of Type III fluids;
- To finalize the laboratory snow test protocol with Type II/III and IV fluids;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To assist the SAE G-12 Ground Equipment Subcommittee in evaluating forced air-assist systems;
- To evaluate the possibility of using a fluid failure sensor in holdover time testing;
- To conduct endurance time tests on non-aluminum plates;
- To examine the effect of heat on Type II, III and IV fluid endurance times;
- To provide support for human factor tactile tests; and
- To conduct general and exploratory de/anti-icing research.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2004-05 are documented in nine reports. The titles of the reports are as follows:

- TP 14443E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2004-05 Winter;
- TP 14444E Winter Weather Impact on Holdover Time Table Format (1995-2005);
- TP 14445E Evaluation of Type IV Fluids Applied Using Forced Air Assist Equipment;
- TP 14446E A Sensor for Determining Anti-Icing Fluid Failure: Phase II;
- TP 14447E Effect of Heat on Endurance Times of Anti-Icing Fluids;
- TP 14448E Aircraft Ground Deicing Fluid Endurance Times on Composite Surfaces;
- TP 14449E Development of Ice Samples for Visual and Tactile Ice Detection Capability Tests;
- TP 14450E Development of Ice Samples for Comparison Study of Human and Sensor Capability to Detect Ice on Aircraft; and
- TP 14451E Aircraft Ground Icing Research General Activities During the 2004-05 Winter.

In addition, the following interim report is being prepared:

- *Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions.*

This report, TP 14447E, has the following objective:

- To conduct endurance time tests with heated Type II, III and IV fluids and to compare these endurance times with endurance times obtained using the standard protocol.

The objective was met by conducting a series of tests under natural and simulated precipitation conditions. Tests were conducted always in pairs, with one fluid applied heated and the other fluid applied according to the standard protocol. The results were compared and the findings are presented in this report.

This research project has been funded by the Civil Aviation Group of Transport Canada with support from the Federal Aviation Administration (FAA).

PROGRAM ACKNOWLEDGEMENTS

This multi-year research program has been funded by the Civil Aviation Group, Transport Canada with support from the Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City, NJ. This program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Transportation Development Centre of Transport Canada, the Federal Aviation Administration, National Research Council Canada, the Meteorological Service of Canada, and several fluid manufacturers.

APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Stephanie Bendickson, Nicolas Blais, Michael Chaput, Sami Chebil, John D'Avirro, Peter Dawson, Stéphane Gosselin, Mark Mayodon, Chris McCormack, Nicoara Moc, Filomeno Pepe, Marco Ruggi, Joey Tiano, Kim Vepsa, and David Youssef.

Special thanks are extended to Barry Myers, Frank Eyre and Yagusha Bodnar, who on behalf of the Transportation Development Centre, have participated, contributed and provided guidance in the preparation of these documents.

Transport Canada / Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No. TP 14447E	2. Project No. B14W	3. Recipient's Catalogue No.
4. Title and Subtitle Effect of Heat on Endurance Times of Anti-Icing Fluids		5. Publication Date October 2005 6. Performing Organization Document No. CM1892.001
7. Author(s) Nicoara Moc		8. Transport Canada File No. 2450-BP-14
9. Performing Organization Name and Address APS Aviation Inc. 6700 Côte-de-Liesse, Suite 102 Montreal, Quebec, H4T 2B5		10. PWGSC File No. TOR-4-37170 11. PWGSC or Transport Canada Contract No. T8156-140243/001/TOR
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) Transport Canada 330 Sparks St., 25th Floor Ottawa, Ontario, K1A 0N5		13. Type of Publication and Period Covered Final 14. Project Officer Antoine Lacroix for Barry Myers

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada. These are available from the Transportation Development Centre (TDC). Nine reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface. This research project has been funded by the Civil Aviation Group of Transport Canada with support from the Federal Aviation Administration (FAA).

16. Abstract

APS Aviation Inc. (APS) undertook a study to conduct endurance time tests with heated Type II, III and IV fluids and to compare these endurance times with endurance times obtained using the standard test protocol. The objective was met by conducting a series of tests under natural and simulated precipitation conditions. Tests were conducted always in pairs, with one fluid applied heated and the other fluid applied according to the standard protocol.

Fluid endurance time testing during natural snow conditions was conducted at the APS test site located at the Montreal-Trudeau Airport, during the winter of 2004-05. To obtain the necessary fluid endurance time data for the freezing precipitation conditions, testing was carried out at the National Research Council Canada (NRC) Climatic Engineering Facility using a sprayer assembly to simulate the required freezing precipitation conditions. During the winter of 2004-05, 19 comparison tests (38 individual tests) were conducted in snow conditions and 20 comparison tests (40 individual tests) were conducted under freezing precipitation conditions. These tests were carried out with five fluid brands and three fluid types.

The comparative tests conducted during simulated freezing precipitation conditions indicated that fluids applied heated diluted faster than those applied at room temperature. Also, the test temperature played an important role in the results of the comparative tests. At -10°C, heat reduced the endurance time of the fluid, whereas at -3°C, it extended the fluid endurance time. Additionally, there seems to be a variation between the various fluid types tested, substantiating that perhaps the effect of heat is fluid dependent.

The comparative tests conducted during natural snow conditions indicated that, typically, heating the fluid prior to application resulted in shorter endurance times in the case of low dilution fluids, namely Type III fluids. The effect of heat seems to increase the endurance time of Type IV fluids. These findings match the results from similar tests conducted during the 2001-02 winter season.

Due to the limited number of tests conducted under both snow and freezing precipitation conditions, currently there is not sufficient data to enable a solid conclusion on the effect of heat on different fluid types and fluid brands. Therefore, it is recommended that the failure mechanisms be further evaluated and analysed by conducting a new series of comparative tests using different fluid types and dilutions at various temperatures and precipitation rates. Furthermore, a series of tests should be conducted on a wing in order to conclude on the validity of the fluid application protocol.

17. Key Words Hot Fluid, Cold Fluid, Natural Snow, Freezing Precipitation, Holdover Time, Heat	18. Distribution Statement Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication) Unclassified	20. Security Classification (of this page) Unclassified	21. Declassification (date) —	22. No. of Pages xvi, 34 apps	23. Price —

CDT/TDC 79-005
Rev. 96

Canada

Transports Canada | Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada TP 14447E	2. N° de l'étude B14W	3. N° de catalogue du destinataire
4. Titre et sous-titre Effect of Heat on Endurance Times of Anti-Icing Fluids		5. Date de la publication Octobre 2005 6. N° de document de l'organisme exécutant CM1892.001
7. Auteur(s) Nicoara Moc		8. N° de dossier - Transports Canada 2450-BP-14
9. Nom et adresse de l'organisme exécutant APS Aviation Inc. 6700, chemin de la Côte-de-Liesse, bureau 102 Montréal (Québec) H4T 2B5		10. N° de dossier - TPSGC TOR-4-37170 11. N° de contrat - TPSGC ou Transports Canada T8156-140243/001/TOR
12. Nom et adresse de l'organisme parrain Centre de développement des transports (CDT) Transport Canada 330 rue Sparks, 25e étage Ottawa (Ontario) K1A 0N5		13. Genre de publication et période visée Final 14. Agent de projet Antoine Lacroix pour Barry Myers

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

Plusieurs rapports de recherche sur les essais de technologies de dégivrage et d'antigivrage ont été produits pour le compte de Transports Canada au cours d'hivers précédents. Ils sont disponibles au Centre de développement des transports (CDT). Neuf rapports (y compris celui-ci) ont été produits dans le cadre du programme de recherche de cet hiver. Leur objet est résumé à la préface. Le présent rapport de recherche a été financé par le Groupe de l'Aviation civile de Transports Canada, appuyé par la Federal Aviation Administration (FAA).

16. Résumé

APS Aviation Inc. (APS) a entrepris une étude pour la tenue d'essais sur l'endurance de liquides chauffés de types II, III et IV et de les comparer à l'endurance obtenue avec le protocole standard d'essais. L'objectif a été atteint en effectuant une série d'essais dans des conditions de précipitations naturelles et simulées. Les essais étaient toujours effectués simultanément, un liquide étant appliqué chauffé alors que l'autre liquide était appliqué selon le protocole standard.

Les essais sur l'endurance des liquides dans des conditions de neige naturelle ont été effectués au site d'essais d'APS de l'Aéroport Montréal-Trudeau au cours de l'hiver 2004-2005. Pour obtenir les données requises sur l'endurance des liquides dans des conditions de précipitations verglaçantes, des essais ont été effectués à l'installation d'ingénierie climatique du Conseil national de recherches Canada (CNRC), à l'aide d'un pulvérisateur pour simuler les conditions requises de précipitations verglaçantes. Au cours de l'hiver 2004-2005, 19 essais comparatifs (38 essais individuels) ont été tenus dans des conditions de neige et 20 essais comparatifs (40 essais individuels) dans des conditions de précipitations verglaçantes. Ces essais ont été effectués avec cinq marques de liquides et trois types de liquides.

Les essais comparatifs effectués dans des précipitations simulées ont démontré que les liquides appliqués chauffés se diluaient plus rapidement que ceux qui étaient appliqués à la température ambiante. De plus, la température des essais a joué un rôle important sur les résultats des essais comparatifs. À -10°C, la chaleur réduisait l'endurance du liquide, alors qu'à -3°C, l'endurance du liquide était prolongée. De plus, il semble y avoir une variation entre les différents types de liquides mis à l'essai, ce qui confirmerait peut-être que l'effet de la chaleur dépend du type de liquide.

Les essais comparatifs effectués dans des conditions de neige naturelle ont démontré que, généralement, le réchauffement du liquide avant son application entraînait une endurance réduite des liquides à faible dilution, à savoir les liquides de type III. La chaleur semble avoir pour effet d'augmenter l'endurance des liquides de type IV. Ces résultats concordent avec ceux d'essais semblables effectués au cours de l'hiver 2001-2002.

En raison du nombre limité d'essais effectués à la fois dans des conditions de neige et de précipitations verglaçantes, il n'y a pas à l'heure actuelle suffisamment de données pour arriver à une conclusion solide sur l'effet de la chaleur sur les différents types et marques de liquides. En conséquence, il est recommandé d'évaluer et d'analyser davantage les mécanismes de rupture à l'aide d'une nouvelle série d'essais comparatifs, utilisant différents types et dilutions de liquides à des températures variées et à différents taux de précipitation. De plus, une série d'essais devrait être effectuée sur une aile, afin d'arriver à une conclusion sur la validité du protocole de validation des liquides.

17. Mots clés Liquide chauffé, liquide froid, neige naturelle, précipitation verglaçante, durée d'efficacité, chaleur	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	—	xvi, 34 ann.	—

CDT/TDC 79-005
Rev. 96

Canada

EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), APS Aviation Inc. (APS) undertook a study to conduct endurance time tests with heated Type II, III and IV fluids and to compare these endurance times with endurance times obtained using the standard test protocol.

The objective was met by conducting a series of tests under natural and simulated precipitation conditions. Tests were conducted always in pairs, with one fluid applied heated and the other fluid applied according to the standard protocol. The results were compared and the findings are presented in this report.

Description and Processing of Data

Fluid endurance time testing during natural snow conditions was conducted at the APS test site located at the Montreal-Trudeau Airport, during the winter of 2004-05. To obtain the necessary fluid endurance time data for the freezing precipitation conditions, testing was carried out at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) using a sprayer assembly to simulate the required freezing precipitation conditions. Testing was conducted by APS personnel, under both natural snow and freezing precipitation conditions.

During the winter of 2004-05, 19 comparison tests (38 individual tests) were conducted in snow conditions and 20 comparison tests (40 individual tests) were conducted under freezing precipitation conditions. These tests were carried out with five fluid brands and three fluid types.

Several parameters were documented during each fluid endurance time test conducted. Data collected pertaining to fluid dilution (fluid Brix) and fluid thickness was measured at set intervals for the duration of the test, while plate surface temperature was logged on an ongoing basis. These parameters were used to construct charts to better illustrate the test surface temperature profiles, as well as fluid thickness decay and fluid dilution.

Results and Conclusions

The conclusions drawn from the tests performed during the winter of 2004-05 are described on the following page, per precipitation condition.

1. Simulated Freezing Precipitation

The comparative tests conducted during simulated freezing precipitation conditions indicated that:

- Fluids applied heated diluted faster than those applied at ambient temperature;
- Data collected with two fluids illustrated a very consistent pattern. Independent of the precipitation condition (drizzle or rain) and the precipitation rate (high or low), the test temperature played an important role in the result of the comparative test. At -10°C, heat reduced the endurance time of the fluid, whereas at -3°C, it extended the fluid endurance time;
- The failure mechanisms described above were not entirely supported by the comparative endurance time testing run with two other fluids. Also, additional data from tests conducted during the 2001-02 winter season showed that the effect of heat did not reduce endurance times. In some cases, a significant improvement was observed; and
- There seems to be a variation among the various fluid types tested, suggesting that perhaps the effect of heat is fluid dependent.

2. Endurance Time Testing During Natural Snow

The comparative tests conducted during natural snow conditions indicated that:

- On average, the hot/cold ratio was 85 percent for Type III fluid and 131 percent for Type IV fluid. This indicated that, on average, heating the fluid prior to application resulted in shorter endurance times in the case of low dilution fluids, namely Type III fluids. Also, the effect of heat seems to increase the endurance time of Type IV fluids. These findings match the results from similar tests conducted during the 2001-02 winter season; and
- There also seems to be a difference among the various Type IV fluid types tested, suggesting that perhaps the effect of heat is fluid dependent.

Recommendations

Due to the limited number of tests conducted under both snow and freezing precipitation conditions, and the slightly contradictory results compared with 2001-02 testing, currently there is no sufficient data to enable a solid conclusion on the effect of heat on different fluid types or even fluid brands. Therefore, it is recommended that the failure mechanisms be further evaluated and analysed by conducting a new series of comparative tests using different fluid types and dilutions at various temperatures and precipitation rates.

Furthermore, for snow conditions, the application protocol used in 2004-05 was initially developed for Type I fluids. The protocol was empirically developed, by comparing temperature profiles from aircraft wings to those of various test surfaces. However, for these comparative tests, an assumption was made that the correspondence between the aircraft wing temperature profile and the profile of the test surface remains unchanged when Type IV is used. This assumption will have to be substantiated by conducting a series of comparative tests on the Jetstar wing. These tests should be conducted before further Type IV hot vs. cold tests are run under snow conditions.

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SOMMAIRE

En vertu d'un contrat avec le Centre de développement des transports (CDT) de Transports Canada (TC), APS Aviation Inc. (APS) a entrepris une étude pour la tenue d'essais sur l'endurance de liquides chauffés de types II, III et IV et de les comparer à l'endurance obtenue avec le protocole standard d'essais.

L'objectif a été atteint en effectuant une série d'essais dans des conditions de précipitations naturelles et simulées. Les essais étaient toujours effectués simultanément, un liquide étant appliqué chauffé alors que l'autre liquide était appliqué selon le protocole standard. Les résultats ont été comparés et les conclusions sont présentées dans le présent rapport.

Description et traitement des données

Les essais sur l'endurance des liquides dans des conditions de neige naturelle ont été effectués au site d'essais d'APS de l'Aéroport Montréal-Trudeau au cours de l'hiver 2004-2005. Pour obtenir les données requises sur l'endurance des liquides dans des conditions de précipitations verglaçantes, des essais ont été effectués à l'installation d'ingénierie climatique du Conseil national de recherches Canada (CNRC), à l'aide d'un pulvérisateur pour simuler les conditions requises de précipitations verglaçantes. Les essais ont été effectués par le personnel d'APS dans des conditions de neige naturelle et de précipitations verglaçantes.

Au cours de l'hiver 2004-2005, 19 essais comparatifs (38 essais individuels) ont été tenus dans des conditions de neige et 20 essais comparatifs (40 essais individuels) dans des conditions de précipitations verglaçantes. Ces essais ont été effectués avec cinq marques de liquides et trois types de liquides.

Plusieurs paramètres ont été documentés au cours de chaque essai tenu sur l'endurance des liquides. Les données recueillies sur la dilution des liquides (degré Brix) et sur l'épaisseur des liquides ont été mesurées à intervalles réguliers pour la durée des essais, alors que la température de la surface de la plaque était enregistrée de façon continue. Ces paramètres ont servi à la préparation de tableaux pour mieux illustrer les profils de température de la surface d'essais, ainsi que la désintégration de l'épaisseur du liquide et sa dilution.

Résultats et conclusions

Les conclusions tirées des essais effectués au cours de l'hiver 2004-2005 sont exposées à la page suivante, par type de précipitations.

1. Précipitation verglaçante simulée

Les essais comparatifs effectués dans des conditions de précipitations verglaçantes ont démontré que :

- Les liquides appliqués chauffés se diluaient plus rapidement que ceux qui sont appliqués à la température ambiante ;

- Les données recueillies sur deux liquides affichaient un modèle très constant. Peu importe la condition de précipitation (bruine ou pluie) et le taux de précipitation (élevé ou faible), la température des essais a joué un rôle important sur le résultat des essais comparatifs. À -10°C, la chaleur réduisait l'endurance du liquide, alors qu'à -3°C, elle en prolongeait l'endurance ;

- Les mécanismes de rupture décrits ci-dessus n'étaient pas entièrement corroborés par les essais comparatifs d'endurance effectués sur deux autres liquides. De plus, les données additionnelles issues d'essais effectués au cours de l'hiver 2001-2002 ont démontré que l'effet de la chaleur ne réduisait pas l'endurance. Dans certains cas, on a noté une amélioration significative ; et

- Il semble y avoir une variation parmi les différents types de liquides mis à l'essai, ce qui suggère que l'effet de la chaleur dépend peut-être du liquide.

2. Essais d'endurance dans la neige naturelle

Les essais comparatifs effectués dans des conditions de neige naturelle ont démontré que :

- En général, le ratio chaud/froid était de 85 pourcent dans le cas des liquides de type III et de 131 pourcent dans le cas des liquides de type IV. Ceci démontre qu'en moyenne, le chauffage du liquide avant son application réduit l'endurance des liquides de faible dilution, à savoir les liquides de type III. De plus, l'effet de la chaleur semble augmenter l'endurance des liquides de type IV. Ces résultats concordent avec ceux d'essais semblables effectués au cours de l'hiver 2001-2002 ; et

- Il semble également y avoir une différence parmi les différents liquides de type IV mis à l'essai, ce qui suggère que l'effet de la chaleur dépend peut-être du liquide.

Recommandations

En raison du nombre limité d'essais effectués dans des conditions de neige et de précipitations verglaçantes, ainsi que des résultats contradictoires comparativement aux essais de 2001-2002, il n'y a pas à l'heure actuelle suffisamment de données pour arriver à une conclusion solide sur l'effet de la chaleur sur les différents types et marques de liquides. En conséquence, il est recommandé d'évaluer et d'analyser davantage les mécanismes de rupture à l'aide d'une nouvelle série d'essais comparatifs, utilisant différents types et dilutions de liquides à des températures variées et à différents taux de précipitation.

En outre, dans des conditions de neige, le protocole d'application utilisé en 2004-2005 a été élaboré initialement pour les liquides de type I. Le protocole a été élaboré de façon expérimentale, en comparant les profils de température sur les ailes d'aéronefs à ceux des diverses surfaces d'essais. Dans le cas de ces essais comparatifs cependant, on a émis l'hypothèse que la correspondance entre le profil de température de l'aile d'aéronef et celui de la surface d'essais demeure inchangé pour l'application de liquide de type IV. Cette hypothèse devra être corroborée par la tenue d'une série d'essais comparatifs sur l'aile du Jetstar. Ces essais devraient être effectués avant la tenue d'autres essais chaud c. froid sur les liquides de type IV dans des conditions de neige.

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GLOSSARY

APS	APS Aviation Inc.
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
MSC	Meteorological Service Canada
NRC	National Research Council Canada
OAT	Outside Air Temperature
SAE	Society of Automotive Engineers, Inc.
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

Under winter precipitation conditions, aircrafts are cleaned with a freezing point depressant fluid and protected against further accumulation by an additional application of such a fluid, possibly thickened to extend the protection time. Aircraft ground deicing had, until recently, never been researched and there is still little understanding of the hazard and of what can be done to reduce the risks posed by the operation of aircraft in winter precipitation conditions. This "winter operations contaminated aircraft – ground" program of research is aimed at overcoming this lack of knowledge.

Over the past several years, the Transportation Development Centre (TDC), Transport Canada (TC) has managed and conducted de/anti-icing related tests at various sites in Canada; it has also coordinated worldwide testing and evaluation of evolving technologies related to de/anti-icing operations with the co-operation of the US Federal Aviation Administration (FAA), the National Research Council (NRC), Atmospheric Environment Services, several major airlines, and deicing fluid manufacturers. The TDC is continuing its research, development, testing and evaluation program.

Under contract to the TDC, APS Aviation Inc. (APS) undertook a test program to investigate the impact of anti-icing fluid application temperature on endurance time performance.

1.1 Background

At an SAE International (SAE) G-12 Holdover Time (HOT) Subcommittee meeting in November 2000, discussion focused on the need to recognize the contribution of heat in the endurance time test procedure for Type I fluids. Research was conducted and it was concluded that an empty aluminum box insulated on all sides except the top would be a suitable simulation of the wing leading edge. As a result, Type I fluids were tested outdoors with this wing leading edge thermal equivalent box, and holdover times were subsequently developed. Because heated Type II and IV fluids at 50/50 and 75/25 concentrations were sometimes being used in one-step deicing procedures, a motion was made to alter the test procedure for these fluids to recognize the contribution of heat and to use as a test surface, the same box that is used in tests with the Type I fluids.

In 2001-02, exploratory tests were conducted to investigate whether heat significantly influences the endurance times for Type II and Type IV fluids. Five different fluid brands were used for these exploratory tests. These tests indicated that heat did not reduce endurance times. In some cases, a significant improvement was observed. However, further investigation was recommended.

1.2 Objective

The objective of this project was to further investigate the impact of the anti-icing fluid application temperature on the endurance time.

The following are the detailed objectives (also see Appendix A):

- Determine effect of heat on Neat and Diluted Type II and Type IV fluid endurance times; and
- Determine effect of heat on Type III fluid (Neat and Diluted) endurance times: currently some operators are considering the use of Type III fluid in the same manner as Type I fluid.

The objective was met by conducting a series of tests under natural and simulated precipitation conditions. Tests were conducted always in pairs, with one fluid applied heated and the other fluid applied according to the standard protocol. The results were compared and the findings are presented in this report.

1.3 Report Format

The following provides short descriptions of main sections of this report:

- Section 2 provides a description of the methodology used to carry out the tests;
- Section 3 presents the data that were collected during natural snow and simulated freezing precipitation conditions;
- Section 4 presents the data analysis of the tests;
- Section 5 presents the conclusions; and
- Section 6 presents the recommendations.

2. METHODOLOGY

This section describes the overall approach, test parameters and experimental procedures followed in this project.

APS measurement instruments and test equipment are calibrated and verified on an annual basis. This calibration is carried out according to a calibration plan derived from approved International Organization for Standardization (ISO) 9001:2000 standards and developed internally by APS.

2.1 Test Site

Fluid endurance time testing during natural snow conditions was conducted at the APS test site located at the Montreal-Trudeau Airport, during the winter of 2004-05. Testing was conducted by APS personnel. The location of the test site is shown on the plan view of the airport in Figure 2.1. The APS test site is located near the Meteorological Service Canada (MSC) automated weather observation station. A view of the test site is shown in Photo 2.1.

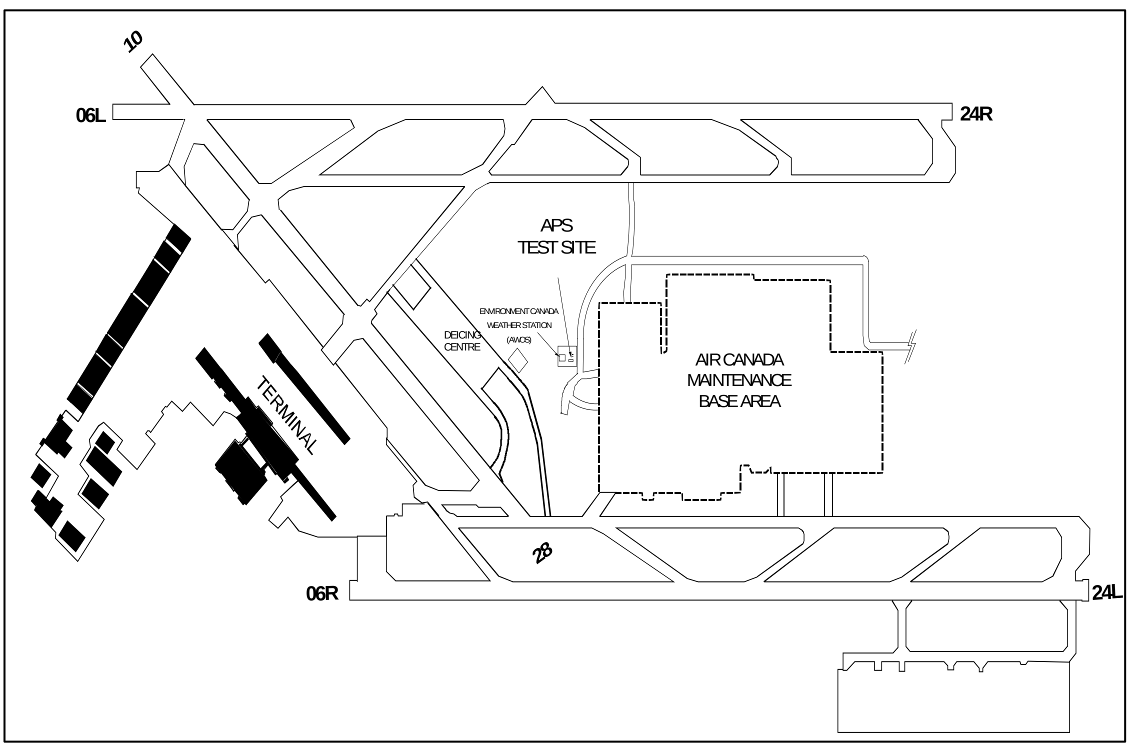


Figure 2.1: Plan View of APS Montreal-Trudeau Airport Test Site

2.2 NRC Climatic Engineering Facility

Fluid endurance time testing in freezing precipitation conditions was carried out at the NRC Climatic Engineering Facility (CEF) (Photo 2.2) using a sprayer assembly to produce the required conditions. Testing was conducted by APS personnel, under freezing rain and freezing drizzle conditions.

2.3 Description of Test Procedures

Comparative endurance time tests were conducted using various fluids at the Montreal-Trudeau Airport test site and at the NRC facility. Standard fluid endurance time test procedures were applied. The tests were conducted simultaneously following the application methods described below.

In an attempt to increase efficiency, testing to determine the impact of fluid application temperature on endurance time was combined with another project related to non-aluminum plate endurance time tests. The test procedure in Appendix B refers to both heated fluid endurance time tests and non-aluminum plate endurance time tests. Photo 2.3 demonstrates the setup used to conduct simultaneous comparative testing for heated fluid endurance time and non-aluminum plate endurance time outdoors. Photo 2.4 demonstrates the setup used to conduct simultaneous comparative testing for heated fluid endurance time and non-aluminum plate endurance time indoors. Only the procedure describing heated fluid endurance time testing is of concern to this report. A complete description of the test procedure used is provided in Appendix B.

2.3.1 Indoor Tests Type II/III/IV Fluids

Position 1: Baseline Standard Test:

1 L of fluid at outside air temperature (OAT) poured (with no spreader) onto an aluminum plate.

Position 2: Heated Fluid Test:

1.0 L of fluid warmed to 60ºC and poured with the warm 12-hole spreader (if fluid is too viscous, then hand pour) onto a plate.

The summary of these application methods is shown in Figure 2.2.

Position 1 (Baseline Standard Test)	Position 2 (Heated Test)
• Plate • 1 L of fluid • Apply at OAT • Poured	• Plate • 1 L of fluid • Applied at 60 ºC • Poured with the 12-hole spreader

Figure 2.2: Position on Stand – Indoor Tests with Type II/III/IV Fluids

2.3.2 Outdoor Tests with Type II/III/IV Fluids

Position 1: Baseline Standard Test:

1 L of fluid at OAT poured (with no spreader) onto an aluminum plate.

Position 2: Heated Fluid Test:

0.5 L of fluid warmed to 60ºC and poured with the warm 12-hole spreader (if fluid is too viscous, then hand pour) onto a box.

The summary of these application methods is shown in Figure 2.3.

Position 1 (Baseline Standard Test)	Position 2 (Heated Test)
• Plate • 1 L of fluid • Apply at OAT • Poured	• Box (empty) @ OAT • 0.5 L of fluid • Applied at 60 ºC • Poured with the 12-hole spreader

Figure 2.3: Position on Stand – Outdoor Tests with Type II/III/IV Fluids

2.4 Data Forms

Two data forms were required for comparative heated fluid endurance time testing:

- Data form for documenting fluid endurance time; and
- Data form for documenting fluid thickness and Brix.

The data forms are provided in the procedure given in Appendix B.

2.5 Equipment

In order to conduct endurance time comparison testing, APS used various pieces of equipment. The key items employed are described below.

2.5.1 Test Surfaces

Baseline standard fluid endurance time testing, for both indoor and outdoor, was conducted using standard aluminum test plates. In the case of outdoor testing, the heated fluid was applied to an empty aluminum box insulated on all sides except the top, as per the Type I fluid application protocol. Testing conducted in 2000-01 to develop the Type I protocol had shown that the box provided a thermal equivalent to the wing leading edge.

2.5.2 Thermistor Probes

Each test plate had a thermistor probe installed at the 15 cm line, inset 1/3 of the width from the edge attached to the underside of the test surface. The box had two thermistors installed at the 15 cm line on the underside of the test surface. Surface temperature data collected was constantly monitored during the test event and was stored in a data logger.

2.5.3 Test Stand

The stand used for standard endurance time tests was used to position the test surfaces. The test plates were placed at a 10º inclination on the test stand and were oriented facing the oncoming wind.

2.5.4 Wet Film Thickness Gauge

Wet film fluid thickness measurements were recorded during endurance time tests. Figure 2.4 shows the schematic of the wet film thickness gauges. Photo 2.5 shows an APS employee conducting a fluid thickness measurement.

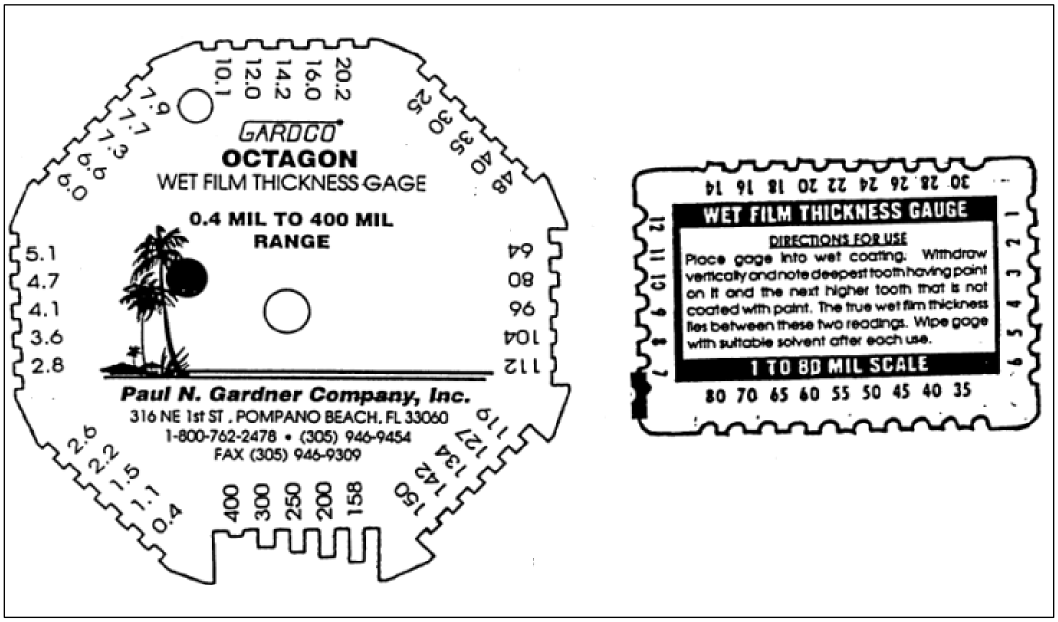


Figure 2.4: Wet Film Thickness Gauges

2.5.5 Brixometer

Brix measurements provided data relevant to the fluid concentration; measuring Brix monitors fluid dilution. Photo 2.6 shows a handheld Brixometer. Photo 2.7 and Photo 2.8 show an APS employee obtaining a fluid sample from the test plate, and using the Brixometer to measure the fluid Brix.

2.5.6 Twelve Hole Fluid Spreader

For both the outdoor and indoor tests, Type II, Type III and Type IV fluids heated to 60°C were applied with the standard twelve-hole spreader (see Photo 2.9), which distributed the fluid evenly along the top of the test plate. The unheated Type II, Type III and Type IV fluids were applied at OAT by freely pouring (without the spreader) over the flat plate test surface (see Photo 2.10).

2.6 Fluids

This section provides information concerning the various fluids used in these tests. Type II, III and IV fluid endurance time testing was conducted using five fluid brands. Table 2.1 lists the fluids used for comparative endurance time testing in snow and freezing precipitation. The fluids were coded, as the interest of this project is to get a generic understanding of the effect of heat.

Table 2.1: Fluids Used for Comparative Endurance Time Testing

Fluid Brand	Fluid Type	Fluid Dilution	Commercial or Experimental Fluid
Fluid A	II	50%, 75%, 100%	Commercial
Fluid B	III	50%, 75%, 100%	Commercial
Fluid C	IV	75%, 100%	Experimental
Fluid D	IV	50%, 75%, 100%	Commercial
Fluid E	IV	100%	Commercial

2.7 Personnel

Three individuals were required to conduct these tests. The test manager measured endurance times. An assistant was required to prepare the fluids, assist with fluid application and collect fluid thickness and dilution measurements. A third person measured precipitation rates.

Photo 2.1: View of APS Test Site

Photo 2.2: Inside View of NRC Climate Engineering Facility

Photo 2.3: Comparative Endurance Time Testing Setup – Outdoors

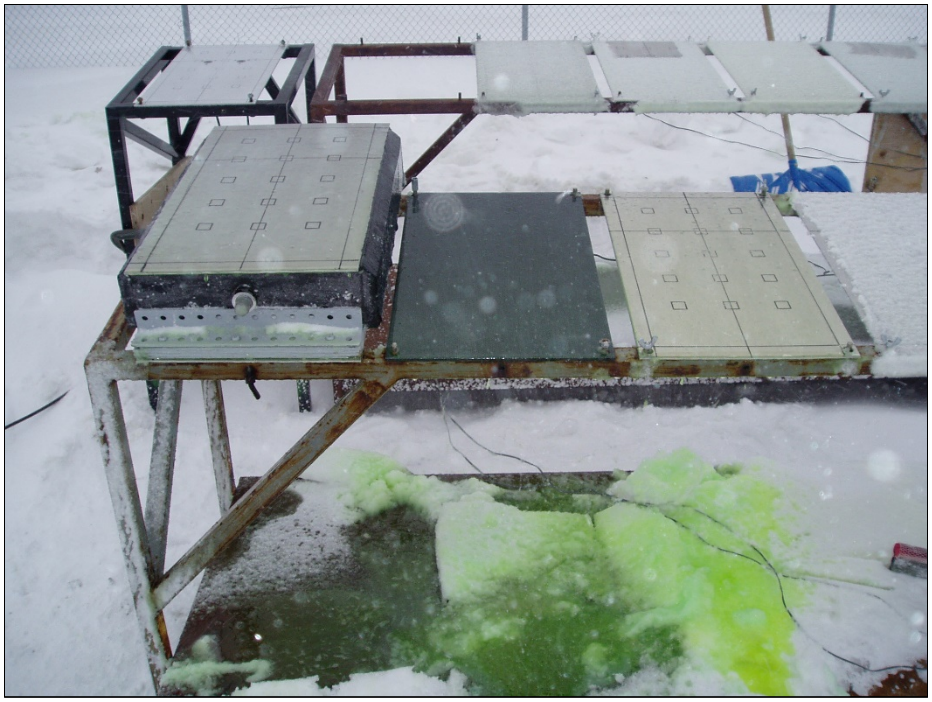


Photo 2.4: Comparative Endurance Time Testing Setup – Indoors

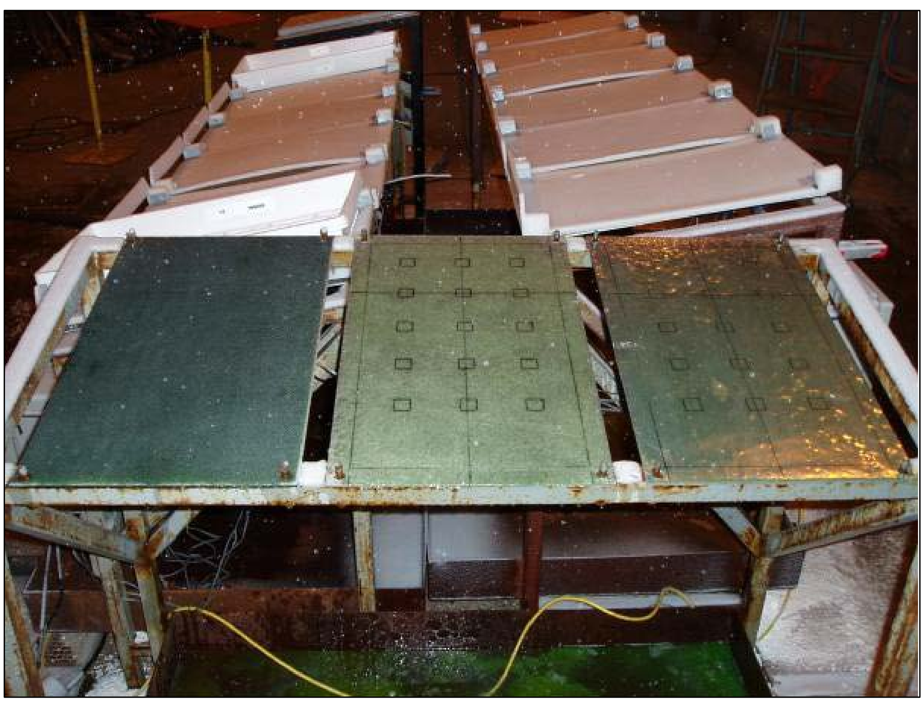


Photo 2.5: Fluid Thickness Measurement Using Wet Film Thickness Gauge

Photo 2.6: Handheld Brixometer

Photo 2.7: Obtaining Fluid Sample for Brix Measurement

Photo 2.8: Using Brixometer to Measure Fluid Brix

Photo 2.9: Fluid Application Using Twelve Hole Spreader

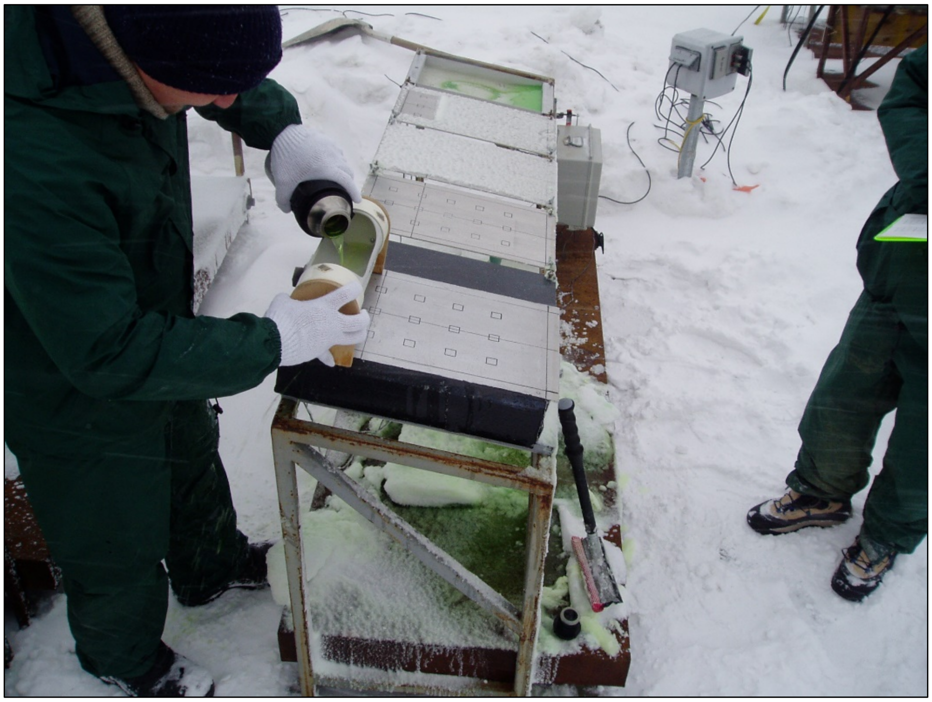
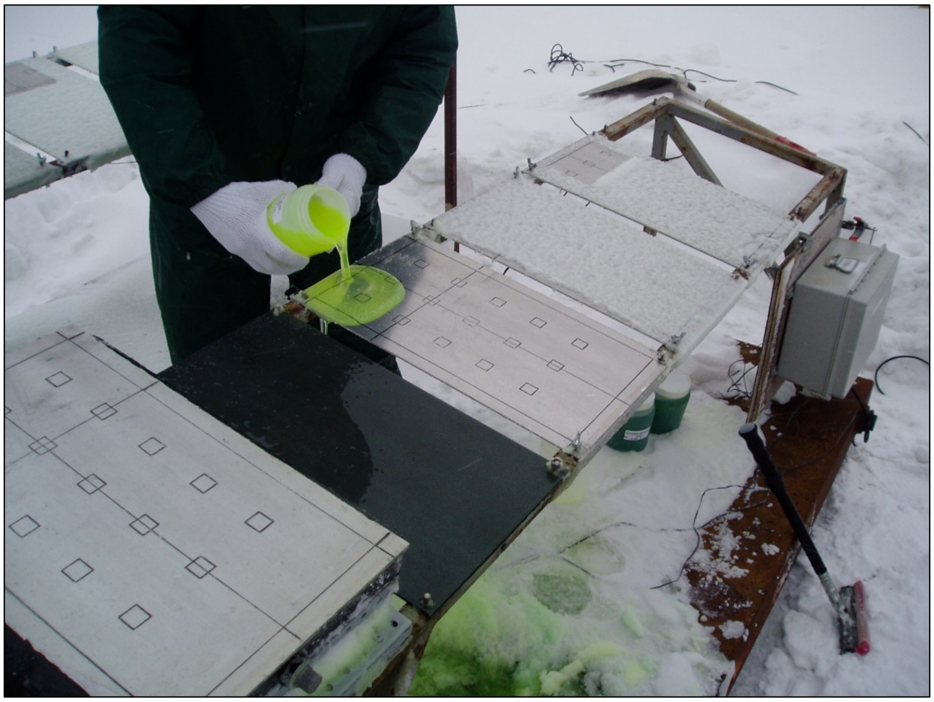


Photo 2.10: Fluid Application by Pouring



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3. DESCRIPTION AND PROCESSING OF DATA

This section describes the data collected from the comparison tests conducted by APS under natural snow and simulated freezing precipitation conditions.

3.1 Log of Tests

During the winter of 2004-05, 19 comparison tests (38 individual tests) were conducted in snow conditions and 20 comparison tests (40 individual tests) were conducted under freezing precipitation conditions. These tests were carried out with five fluid brands and three fluid types. To facilitate the accessibility of the data collected, two logs were created for the series of tests, Table 3.1 lists the tests conducted at the NRC CEF and Table 3.2 lists the tests conducted at the Montreal-Trudeau test site. The logs provide relevant information for each test, as well as final values used for the data analysis. Each row contains data specific to one test. Test numbers are not sequential, as comparative tests using heated and non-heated fluids were conducted in conjunction with testing on non-aluminum surfaces; data that was not of concern to this report was removed from the data log. The following is a brief description of the column headings for the test logs:

Test No.:	Exclusive number identifying each test;
Date:	Date when the test was conducted;
Fluid Dilution:	Aircraft anti-icing fluid glycol concentration;
Fluid Name:	A unique code designating a fluid brand name;
Fluid Type:	Aircraft anti-icing fluid type;
Fluid Applic. Temp:	Aircraft anti-icing fluid application temperature;
Test Surface:	Surface used for testing: flat plate or box;
Fail Time:	Measured fluid endurance time;
Precipitation Rate:	Average precipitation rate (in $g/dm^2/h$) collected by two precipitation pans at set intervals for the duration of the test session;
Average Test Temp:	(Table 3.1) The average ambient temperature of the CEF during the test,
Average OAT:	(Table 3.2) The average hourly outside ambient temperature (in degrees Celsius) provided by Environment Canada;
Average Wind Speed:	(Table 3.2) The average hourly wind speed, (in $g/dm^2/h$), provided by Environment Canada; and
Chart:	Designates whether the data collected during the test was plotted and a chart was produced.

Table 3.1: Simulated Freezing Precipitation Tests 2004-05

Test No.	Date	Fluid Dilution	Fluid Name	Fluid Type	Fluid Applic. Temp. (°C)	Test Surface	Fail Time (min.)	Precipitation Rate (g/dm²/h)	Avg. Test Temp. (°C)	Condition	Chart
1	Apr-05-05	100%	Fluid B	3	OAT	Aluminum	21.1	5.3	-10.4	ZD	X
2	Apr-05-05	100%	Fluid B	3	60	Aluminum Heated	15.8	5.3	-10.4	ZD	X
3	Apr-05-05	75%	Fluid C	4	OAT	Aluminum	14.5	5.3	-10.0	ZD	X
4	Apr-05-05	75%	Fluid C	4	60	Aluminum Heated	10.5	5.3	-9.9	ZD	X
6	Apr-05-05	75%	Fluid A	2	OAT	Aluminum	26.3	13.2	-10.5	ZD	X
7	Apr-05-05	75%	Fluid A	2	60	Aluminum Heated	21.6	13.2	-10.4	ZD	X
8	Apr-05-05	75%	Fluid B	3	OAT	Aluminum	8.7	13.2	-10.5	ZD	X
9	Apr-05-05	75%	Fluid B	3	60	Aluminum Heated	8.2	13.2	-10.5	ZD	X
10	Apr-05-05	100%	Fluid D	4	OAT	Aluminum	29.3	13.2	-10.3	ZD	X
11	Apr-05-05	100%	Fluid D	4	60	Aluminum Heated	32.0	13.2	-10.3	ZD	X
13	Apr-05-05	100%	Fluid A	2	OAT	Aluminum	24.8	25.2	-9.9	ZR	X
14	Apr-05-05	100%	Fluid A	2	60	Aluminum Heated	19.8	25.2	-9.8	ZR	X
15	Apr-05-05	75%	Fluid A	2	OAT	Aluminum	14.3	25.2	-10.1	ZR	X
16	Apr-05-05	75%	Fluid A	2	60	Aluminum Heated	11.3	25.2	-10.1	ZR	X
19	Apr-06-05	100%	Fluid B	3	OAT	Aluminum	15.5	13.4	-10.9	ZR	X
20	Apr-06-05	100%	Fluid B	3	60	Aluminum Heated	9.5	13.4	-10.8	ZR	X
23	Apr-06-05	75%	Fluid B	3	OAT	Aluminum	10.8	13.4	-10.5	ZR	X
24	Apr-06-05	75%	Fluid B	3	60	Aluminum Heated	9.0	13.4	-10.5	ZR	X
26	Apr-06-05	75%	Fluid B	3	OAT	Aluminum	11.4	13.3	-3.2	ZR	X
27	Apr-06-05	75%	Fluid B	3	60	Aluminum Heated	14.9	13.3	-3.2	ZR	X
28	Apr-06-05	50%	Fluid A	2	OAT	Aluminum	9.7	13.3	-3.2	ZR	X
29	Apr-06-05	50%	Fluid A	2	60	Aluminum Heated	15.1	13.3	-3.2	ZR	X
30	Apr-06-05	50%	Fluid B	3	OAT	Aluminum	7.8	13.3	-3.1	ZR	X
31	Apr-06-05	50%	Fluid B	3	60	Aluminum Heated	16.7	13.3	-3.1	ZR	X
32	Apr-06-05	75%	Fluid A	2	OAT	Aluminum	14.2	25.5	-3.1	ZR	X
33	Apr-06-05	75%	Fluid A	2	60	Aluminum Heated	16.3	25.5	-3.1	ZR	X
34	Apr-06-05	100%	Fluid B	3	OAT	Aluminum	10.5	25.5	-3.1	ZR	X
35	Apr-06-05	100%	Fluid B	3	60	Aluminum Heated	13.8	25.5	-3.2	ZR	X
36	Apr-06-05	75%	Fluid C	4	OAT	Aluminum	32.5	25.5	-3.1	ZR	X
37	Apr-06-05	75%	Fluid C	4	60	Aluminum Heated	22.0	25.5	-3.1	ZR	X
41	Apr-07-05	50%	Fluid A	2	OAT	Aluminum	11.8	5.4	-3.3	ZD	X
42	Apr-07-05	50%	Fluid A	2	60	Aluminum Heated	16.8	5.4	-3.3	ZD	X
43	Apr-07-05	50%	Fluid B	3	OAT	Aluminum	9.1	5.4	-3.2	ZD	X
44	Apr-07-05	50%	Fluid B	3	60	Aluminum Heated	16.1	5.4	-3.2	ZD	X
45	Apr-07-05	75%	Fluid B	3	OAT	Aluminum	8.8	13.4	-3.0	ZD	X
46	Apr-07-05	75%	Fluid B	3	60	Aluminum Heated	16.6	13.4	-3.0	ZD	X
47	Apr-07-05	50%	Fluid A	2	OAT	Aluminum	6.8	13.4	-3.1	ZD	X
48	Apr-07-05	50%	Fluid A	2	60	Aluminum Heated	16.3	13.4	-3.1	ZD	X
49	Apr-07-05	50%	Fluid D	4	OAT	Aluminum	9.2	13.4	-3.1	ZD	X
50	Apr-07-05	50%	Fluid D	4	60	Aluminum Heated	16.2	13.4	-3.1	ZD	X

ZD – Freezing Drizzle
ZR – Freezing Rain

Table 3.2: Natural Snow Tests 2004-05

Test No.	Date	Fluid Dilution	Fluid Name	Fluid Type	Fluid Applic. Temp. (°C)	Test Surface	Fail Time (min.)	Precipitation Rate (g/dm²/h)	Avg. OAT (°C)	Avg. Wind Speed (km/h)	Chart
2	Jan-06-05	100%	Fluid B	3	OAT	Aluminum	10.0	28.7	-12.2	32	
3	Jan-06-05	100%	Fluid B	3	60	Box	7.0	27.2	-12.2	32	
5	Jan-06-05	75%	Fluid B	3	OAT	Aluminum	8.0	31.6	-12.3	26	
6	Jan-06-05	75%	Fluid B	3	60	Box	5.0	31.0	-12.3	26	
7	Jan-06-05	75%	Fluid B	3	OAT	Aluminum	7.0	37.1	-12.1	30	
9	Jan-06-05	75%	Fluid B	3	60	Box	5.5	37.3	-12.1	30	
11	Feb-10-05	100%	Fluid B	3	OAT	Aluminum	36.0	5.6	-5.7	37	X
12	Feb-10-05	100%	Fluid B	3	60	Box	36.8	5.7	-5.7	37	X
14	Feb-10-05	75%	Fluid B	3	OAT	Aluminum	17.8	9.6	-5.1	37	X
15	Feb-10-05	75%	Fluid B	3	60	Box	18.8	9.7	-5.1	37	X
17	Feb-10-05	75%	Fluid C	4	OAT	Aluminum	57.0	8.8	-5.4	33	X
18	Feb-10-05	75%	Fluid C	4	60	Box	87.0	7.3	-5.4	33	X
19	Feb-21-05	75%	Fluid D	4	60	Box	43.7	4.4	-14.4	28	X
21	Feb-21-05	75%	Fluid D	4	OAT	Aluminum	30.5	4.1	-14.4	28	X
22	Feb-21-05	100%	Fluid D	4	60	Box	100.3	5.8	-14.3	28	X
24	Feb-21-05	100%	Fluid D	4	OAT	Aluminum	58.3	6.0	-14.3	28	X
25	Feb-21-05	75%	Fluid C	4	60	Box	46.2	3.8	-13.5	30	X
27	Feb-21-05	75%	Fluid C	4	OAT	Aluminum	39.3	3.9	-13.5	30	X
28	Feb-21-05	100%	Fluid E	4	60	Box	173.5	4.3	-12.2	22	X
30	Feb-21-05	100%	Fluid E	4	OAT	Aluminum	152.3	3.5	-12.2	22	X
31	Feb-21-05	75%	Fluid B	3	60	Box	12.0	13.4	-6.3	17	X
33	Feb-21-05	75%	Fluid B	3	OAT	Aluminum	16.0	13.8	-6.3	17	X
34	Feb-21-05	100%	Fluid B	3	60	Box	15.2	13.3	-6.3	17	X
36	Feb-21-05	100%	Fluid B	3	OAT	Aluminum	21.3	14.0	-6.2	17	X
37	Feb-21-05	100%	Fluid C	4	60	Box	62.3	13.0	-5.9	22	X
39	Feb-21-05	100%	Fluid C	4	OAT	Aluminum	67.0	12.6	-5.9	23	X
42	Mar-07-05	75%	Fluid C	4	60	Box	20.3	11.9	-13.0	28	X
44	Mar-07-05	75%	Fluid C	4	OAT	Aluminum	18.2	11.9	-13.0	28	X
45	Mar-07-05	100%	Fluid B	3	60	Box	30.0	7.5	-12.8	31	X
47	Mar-07-05	100%	Fluid B	3	OAT	Aluminum	31.1	7.8	-12.8	31	X
48	Mar-07-05	75%	Fluid B	3	60	Box	20.7	5.2	-12.2	32	X
50	Mar-07-05	75%	Fluid B	3	OAT	Aluminum	23.2	4.5	-12.2	32	X
51	Mar-07-05	100%	Fluid E	4	60	Box	162.0	7.2	-10.6	32	X
53	Mar-07-05	100%	Fluid E	4	OAT	Aluminum	111.2	4.6	-10.5	32	X
54	Mar-07-05	100%	Fluid B	3	60	Box	24.5	11.1	-11.3	28	X
56	Mar-07-05	100%	Fluid B	3	OAT	Aluminum	26.9	11.0	-11.3	28	X
57	Mar-07-05	75%	Fluid B	3	60	Box	15.9	10.1	-10.9	27	X
59	Mar-07-05	75%	Fluid B	3	OAT	Aluminum	17.6	9.4	-10.9	27	X

3.2 Detailed Temperature Profiles

Several parameters were documented during each fluid endurance time test. Fluid dilution (fluid Brix) and fluid thickness were measured at set intervals for the duration of the test, while plate surface temperature was logged on an ongoing basis. These parameters were used to construct charts to better illustrate the test surface temperature profiles, as well as fluid thickness decay and fluid dilution.

Figure 3.1 and Figure 3.2 present the detailed temperature, fluid dilution and fluid thickness profile charts constructed for a comparative natural snow endurance time test conducted using a Type IV fluid applied to a box and to a standard test plate, respectively.

Figure 3.1 and Figure 3.2 demonstrate the surface temperatures and freeze point mechanisms that influence fluid failure. The dilution of the fluid is indicated on the charts in negative Brix values "(-) Brix" as conversion charts of Brix values to fluid freeze point temperatures were not available for many of the fluids tested.

As seen on the charts, the surface temperature profile and the fluid dilution curve gradually approach an ultimate value, ambient temperature. The point where the two curves come closest is the expected endurance time. In other words, freezing is expected to occur when the fluid freeze point and the surface temperature match.

Similar charts were completed for each test conducted, and are included in Appendix C.

3.3 Distribution of 2004-05 Simulated Precipitation Conditions

During the 2004-05 season, 20 comparison tests (40 individual tests) were conducted under freezing precipitation conditions. These tests were carried out with four fluid brands and three fluid types, under freezing drizzle and freezing rain. For both conditions, tests were carried out at -3°C and -10°C under the low and high precipitation rate limits specific to each weather condition.

3.4 Distribution of 2004-05 Winter Weather

During the winter of 2004-05, comparative endurance time testing for aluminum test plates was conducted during 4 natural snow events. A total of 19 comparative tests were conducted; 38 individual tests were performed. A distribution of the manually measured precipitation rate and the recorded wind speed was tabulated for the entire data set. Figure 3.3 and Figure 3.4 present the results.

The distribution of manually measured precipitation rates showed that 47 percent of the tests were conducted during snow conditions with precipitation rates below 10 g/dm²/h. Very light and light snow conditions typically account for the majority of the deicing operations performed at the Montreal-Trudeau Airport. The distribution of recorded wind speeds showed that 68 percent of the tests were conducted during wind speeds greater than 27 km/h.

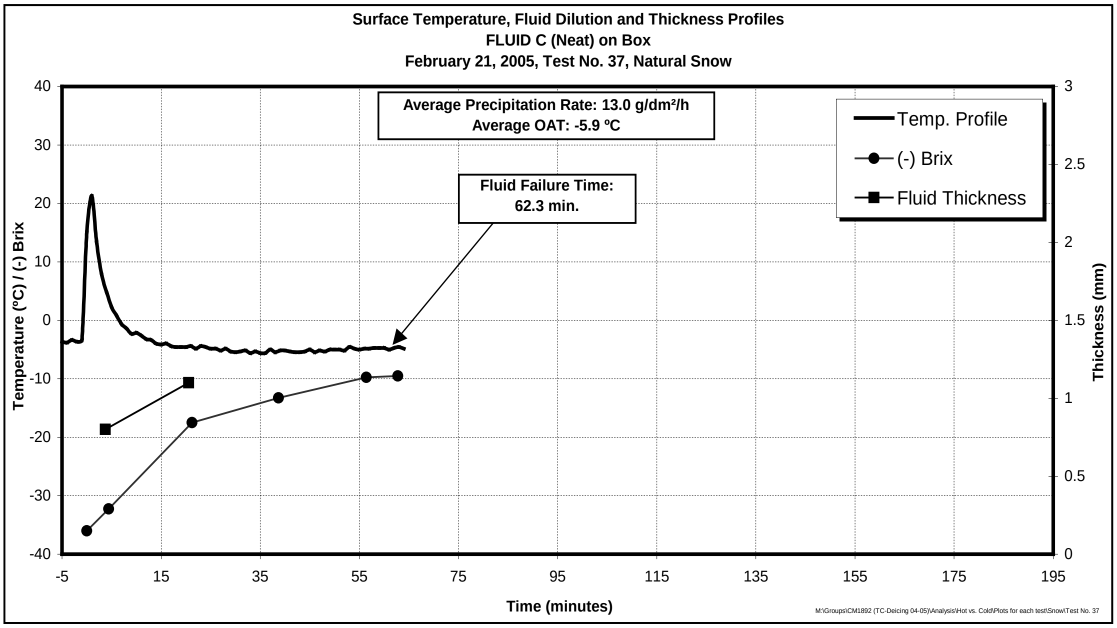

Figure 3.1: Type IV Fluid Endurance Time on Aluminum Box Surface

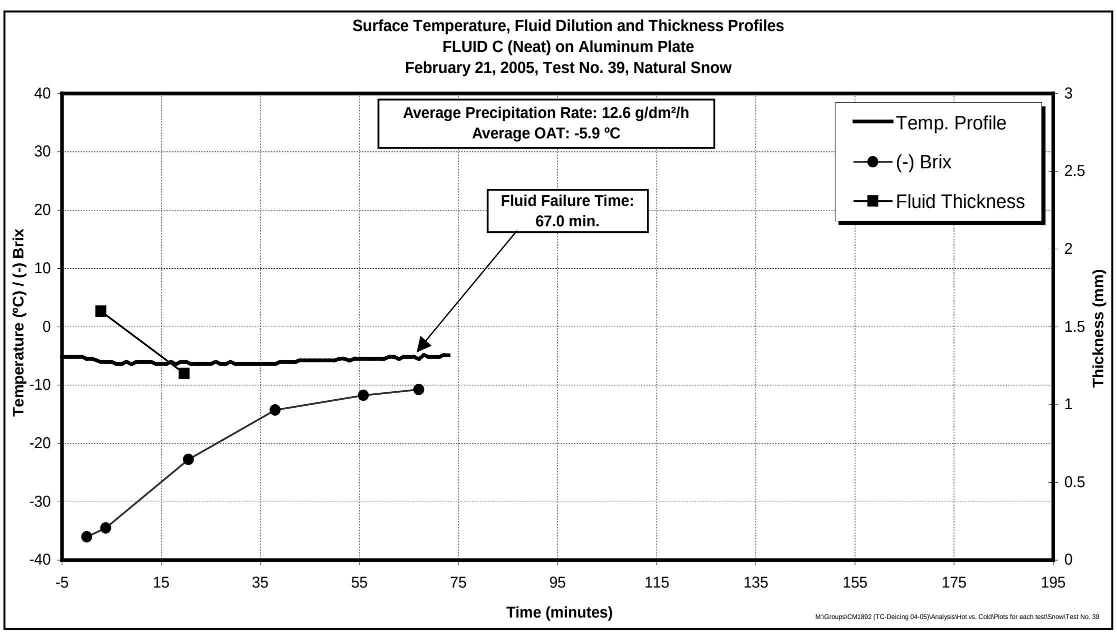

Figure 3.2: Type IV Fluid Endurance Time on Aluminum Test Plate Surface

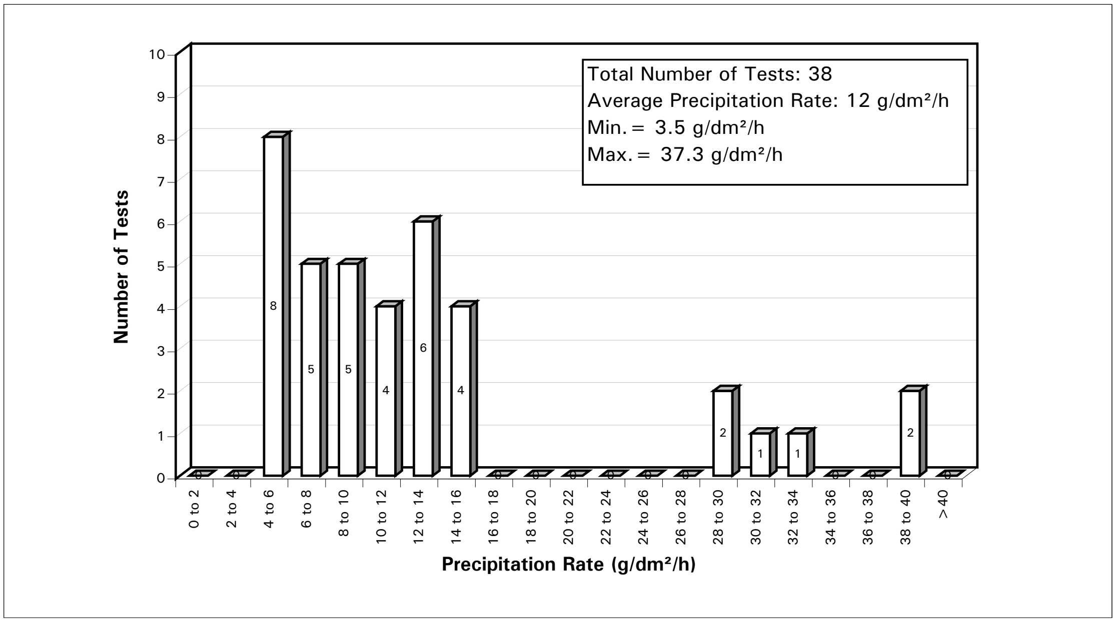

Figure 3.3: Distribution of Precipitation Rate – Natural Snow Tests 2004-05

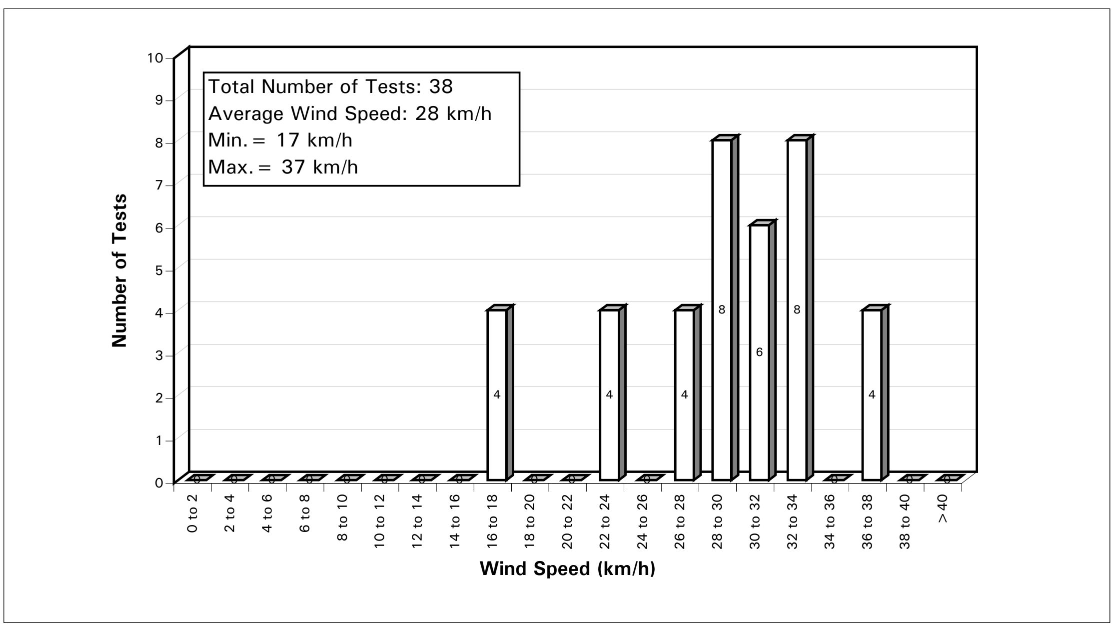

Figure 3.4: Distribution of Wind Speed – Natural Snow Tests 2004-05

4. ANALYSIS AND OBSERVATIONS

In this section, the data collected for each test is analysed and discussed. For each test, the fluid endurance time measured using heated fluid was compared to the fluid endurance time measured using standard application protocols.

4.1 General Observations

Comparative analysis of the recorded endurance times was performed both for tests conducted in simulated freezing precipitation and in natural snow. The results are charted in Figure 4.1 and Figure 4.2 respectively. Adjacent pairs of bars represent the endurance time (in minutes) measured with the hot and the cold fluids. Pertinent test information for each comparative test is labelled: fluid type, fluid dilution, rate of precipitation and temperature.

4.1.1 Freezing Precipitation

Forty comparative endurance time tests (20 pairs) were run in freezing precipitation conditions. Figure 4.1 demonstrates the results obtained. As seen on the graph, endurance time tests were run under eight distinct precipitation conditions:

1. Freezing Rain, Temperature -3°C, Precipitation Rate 13 g/dm²/h (ZR3L);
2. Freezing Rain, Temperature -3°C, Precipitation Rate 25 g/dm²/h (ZR3H);
3. Freezing Rain, Temperature -10°C, Precipitation Rate 13 g/dm²/h (ZR10L);
4. Freezing Rain, Temperature -10°C, Precipitation Rate 25 g/dm²/h (ZR10H);
5. Freezing Drizzle, Temperature -3°C, Precipitation Rate 5 g/dm²/h (ZD3L);
6. Freezing Drizzle, Temperature -3°C, Precipitation Rate 13 g/dm²/h (ZD3H);
7. Freezing Drizzle, Temperature -10°C, Precipitation Rate 5 g/dm²/h (ZD10L); and
8. Freezing Drizzle, Temperature -10°C, Precipitation Rate 13 g/dm²/h (ZD10H).

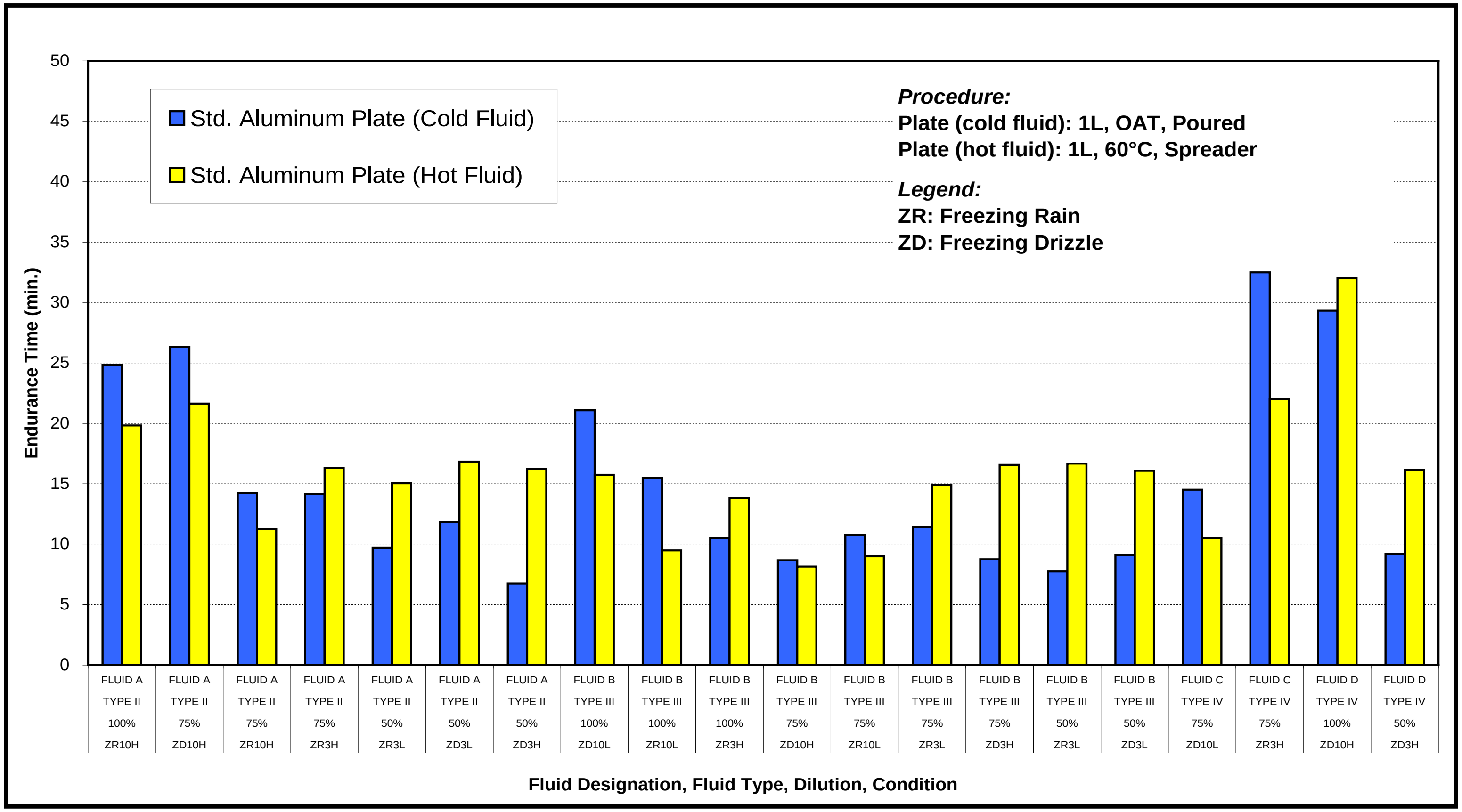

Figure 4.1: Failure Time Comparison – Freezing Precipitation

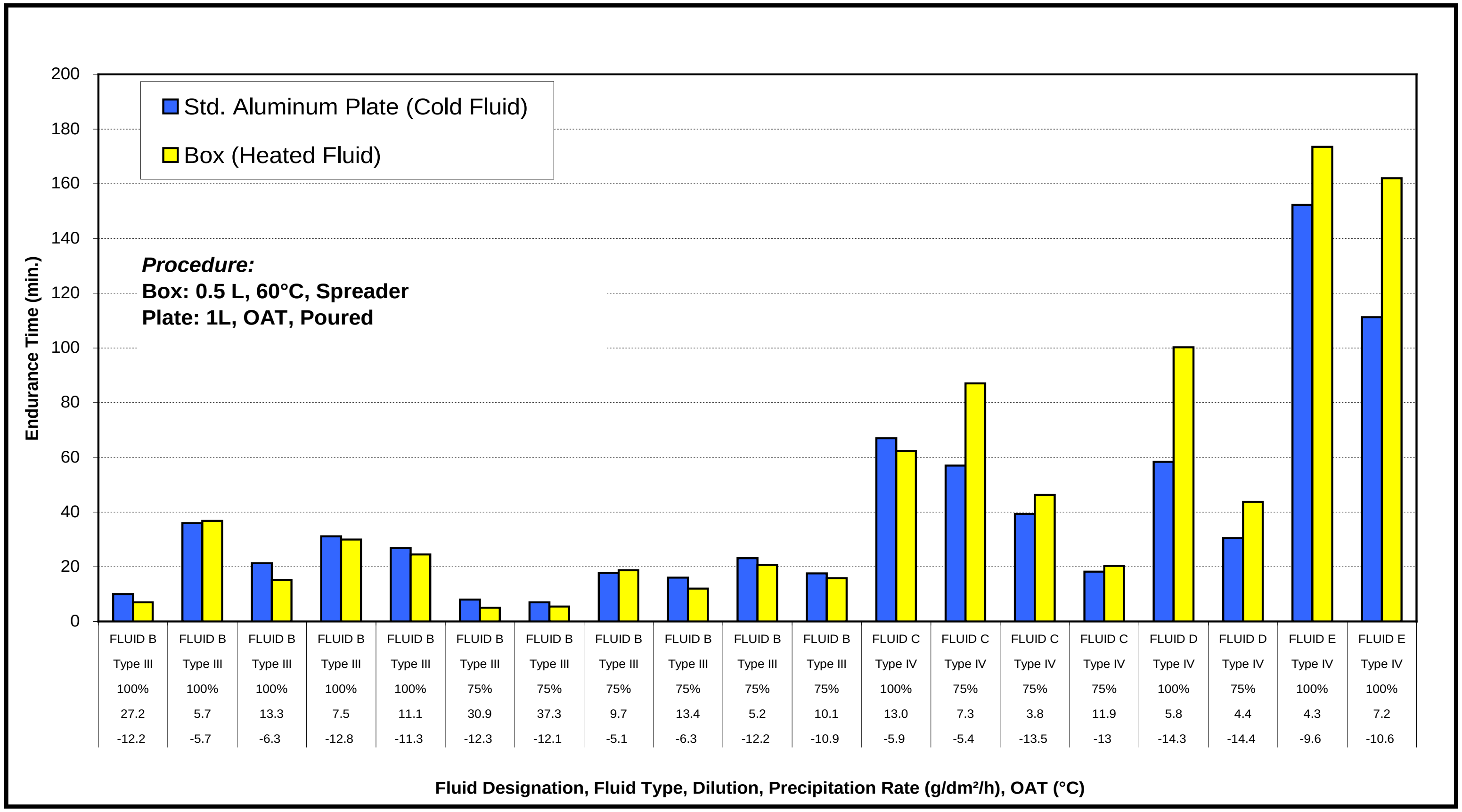

Figure 4.2: Failure Time Comparison – Natural Snow

To correlate the test results from the heated-fluid test plate to the standard protocol test plate, the fluid endurance times were compared. The comparison is presented in Table 4.1.

Table 4.1 presents the results obtained for freezing precipitation tests. The percentage ratio between the endurance time of the heated test and that of the standard protocol test was calculated for each test; the average and standard deviation of the data set was also calculated.

On average, under simulated freezing precipitation conditions, the endurance times obtained with hot fluid were longer (by 24 percent) than those obtained using the standard application protocol. However, the standard deviation was high, at 53 percent.

As seen in Table 4.1, endurance testing conducted with Fluid A and Fluid B accounts for eighty percent of all tests.

Table 4.1: Endurance Time Ratio Analysis – Freezing Precipitation

Fluid Code	Fluid Type	Endurance Time (Cold Fluid) min.	Endurance Time (Hot Fluid) min.	Endurance Time Ratio (Hot / Cold)
FLUID A	TYPE II	24.8	19.8	80%
FLUID A	TYPE II	26.3	21.6	82%
FLUID A	TYPE II	14.3	11.3	79%
FLUID A	TYPE II	14.2	16.3	115%
FLUID A	TYPE II	9.7	15.1	155%
FLUID A	TYPE II	11.8	16.8	142%
FLUID A	TYPE II	6.8	16.3	241%
FLUID B	TYPE III	21.1	15.8	75%
FLUID B	TYPE III	15.5	9.5	61%
FLUID B	TYPE III	10.5	13.8	132%
FLUID B	TYPE III	8.7	8.2	94%
FLUID B	TYPE III	10.8	9.0	84%
FLUID B	TYPE III	11.4	14.9	131%
FLUID B	TYPE III	8.8	16.6	189%
FLUID B	TYPE III	7.8	16.7	215%
FLUID B	TYPE III	9.1	16.1	177%
FLUID C	TYPE IV	14.5	10.5	72%
FLUID C	TYPE IV	32.5	22.0	68%
FLUID D	TYPE IV	29.3	32.0	109%
FLUID D	TYPE IV	9.2	16.2	176%

Average:	124%
Standard Deviation:	53%

A closer look at the data collected with Fluid A and Fluid B illustrates a very consistent pattern. Independent of the precipitation condition (drizzle or rain) and the precipitation rate (high or low), the ambient test temperature seems to play an important role in the results of the comparative test.

As a general observation, valid for all fluid types, fluids applied heated diluted faster than those applied at ambient temperature. A possible explanation of this effect is that, upon application, the hot fluid runs off the plate faster than the cold fluid, resulting in a thinner layer of fluid throughout the test. Under similar precipitation rates, the hot fluid will consequently dilute faster.

As mentioned above, the actual test temperature seems to control whether the hot fluid fails first. As can be found in the detailed charts presented in Appendix C, in the case of Fluid A and Fluid B, all tests conducted at a temperature of -10°C resulted in shorter endurance times for the fluids applied heated. Similarly, all tests conducted at -3°C yielded longer endurance times for the fluids applied heated. The explanation is that, even at constantly higher dilution rates compared to the cold fluid, heated fluids showed a longer endurance time at -3°C due to their heat capacity. In other words, the extended endurance time came as a result of the fluid temperature, which had to drop below 0°C in order for the fluid to fail. In the case of the -10°C test, the fluid temperature dropped much faster, and consequently the higher dilution rate of the heated fluid became prevalent and led to a shorter endurance time.

The failure mechanisms described above are not entirely supported by the comparative endurance time testing run with Fluid C and Fluid D. The temperature profiles for these two Type IV fluids do not clearly demonstrate this theory. In the case of Fluid C, the endurance time of the heated fluid was always shorter than that of the cold fluid. In the case of Fluid D, the endurance time of the heated fluid was always longer than that of the cold fluid. However, testing with these two fluids consisted of only 20 percent of all testing.

Additional data was available from tests conducted during the 2001-02 winter season. As presented in Section 5 of TC report, TP 13994E, *Generation of Holdover Times Using the New Type I Fluid Test Protocol* (1), a series of 24 comparative tests (12 pairs) were conducted using the same protocol applied in 2004-05. Tests were conducted with Type II and Type IV fluids at different dilutions. The tests showed that heat did not reduce endurance times. In some cases, a significant improvement was observed.

4.1.2 Natural Snow

Thirty-eight comparative endurance time tests (19 pairs) were run in conditions of natural snow. Figure 4.2 presents the results obtained.

To correlate the heated-fluid test plate to the standard protocol test plate, a comparison of the measured fluid endurance times was made to evaluate any existing relationship and is presented in Table 4.2.

The percentage ratio between the endurance time of the heated test and that of the standard protocol test was calculated for each test; the average and standard deviation of the data set was also calculated. Table 4.2 demonstrates the results obtained for natural snow.

Table 4.2: Endurance Time Ratio Analysis – Natural Snow

Fluid Code	Fluid Type	Endurance Time (Cold Fluid) min.	Endurance Time (Hot Fluid) min.	Endurance Time Ratio (Hot / Cold)
FLUID B	Type III	10.0	7.0	70%
FLUID B	Type III	36.0	36.8	102%
FLUID B	Type III	21.3	15.2	71%
FLUID B	Type III	31.1	30.0	96%
FLUID B	Type III	26.9	24.5	91%
FLUID B	Type III	8.0	5.0	63%
FLUID B	Type III	7.0	5.5	79%
FLUID B	Type III	17.8	18.8	106%
FLUID B	Type III	16.0	12.0	75%
FLUID B	Type III	23.2	20.7	89%
FLUID B	Type III	17.6	15.9	90%
FLUID C	Type IV	67.0	62.3	93%
FLUID C	Type IV	57.0	87.0	153%
FLUID C	Type IV	39.3	46.2	118%
FLUID C	Type IV	18.2	20.3	112%
FLUID D	Type IV	58.3	100.3	172%
FLUID D	Type IV	30.5	43.7	143%
FLUID E	Type IV	152.3	173.5	114%
FLUID E	Type IV	111.2	162.0	146%

Average:	104%
Standard Deviation:	31%

On average, under natural snow conditions, the endurance times obtained with hot fluid were slightly longer (by 4 percent) when compared with those obtained using the standard application protocol. However, the standard deviation was fairly high, at 31 percent. A closer look at the data also shows that the hot/cold ratio has an average of 85 percent for Type III fluid and an average of 131 percent for Type IV fluid. This indicated that, on average, heating the fluid prior to application resulted in shorter endurance times in the case of less viscous fluids, namely Type III fluids. By the same token, heat seems to have a beneficial effect on the endurance time of Type IV fluids, extending their endurance time by roughly, 31 percent. Moreover, there also seems to be a difference between the various Type IV fluid types tested, illustrating that perhaps the effect of heat is fluid dependent.

A more in-depth look at the detailed charts presented in Appendix C shows that for Type III fluid, heat, in most cases, leads to a reduced fluid layer thickness, and consequently, to an accelerated rate of fluid dilution (see tests No. 48, 50 in Appendix C). As a result, heat produced a diminished fluid endurance time. In most cases, at the time of fluid failure, both surfaces (heated and cold) are at the same temperature, indicating that the heat from the hot fluid does not seem to produce a long-lasting effect on the test surface.

In the case of Type IV fluids, the extended endurance times recorded when hot fluid is applied do not seem to be caused by an elevated surface temperature, at the time of fluid failure both surfaces (heated and cold) being at the same temperature. However, heat may have an influence on the fluid dilution rate. Both surfaces fail at similar glycol concentration values. As observed during these tests, the heated fluid typically dilutes at a slower rate than the cold fluid, generating a longer endurance. Also, heat leads to an increase in fluid thickness, an effect that is present throughout the duration of the experiment time (see tests No. 28, 30 in Appendix C).

These findings match the results from similar tests conducted during the 2001-02 winter season. As presented in Section 5 of TC report, TP 13994E, *Generation of Holdover Times Using the New Type I Fluid Test Protocol* (1), a series of 18 comparative tests (9 pairs) were conducted using a protocol fairly similar to that applied in 2004-05. Tests were conducted with Type IV fluids and two dilutions of Type II fluids. The hot/cold endurance time ratios recorded in 2001-02 decreased as the fluid dilution increased.

However, due to the limited number of tests conducted so far, there is not sufficient data to enable a solid conclusion on the effect of heat on different fluid types and even fluid brands. It is recommended that the failure mechanisms be further evaluated and analysed by conducting a new series of comparative tests using different fluid types and dilutions at various temperatures and precipitation rates.

Moreover, the application protocol used in 2004-05 was initially developed for Type I fluids. The protocol was empirically developed, by comparing temperature profiles from aircraft wings to those of various test surfaces. However, for these comparative tests, an assumption was made that the correspondence between the aircraft wing profile and the profile of the test surface remains valid when Type IV is used. This assumption will have to be substantiated by conducting a series of comparative tests on the Jetstar wing. These tests should be conducted before further Type IV hot vs. cold tests are run.

4.1.3 Summary of Results

In conclusion, by putting all of the information together, there seems to be a variation between the various fluid types tested, indicating that perhaps the effect of heat is fluid dependent.

However, due to the limited number of tests conducted, there is not sufficient data to enable a solid conclusion on the effect of heat on different fluid types and even fluid brands. It is recommended that the failure mechanisms be further evaluated and analysed by conducting a new series of comparative tests using different fluid types and dilutions under various precipitation conditions.

5. CONCLUSIONS

The conclusions drawn from the tests performed during the winter of 2004-05 are described in this section.

5.1 Endurance Time Testing During Simulated Freezing Precipitation

The comparative tests conducted during simulated freezing precipitation conditions indicated that:

- Fluids applied heated diluted faster than those applied at ambient temperature;
- Data collected with two fluids illustrated a very consistent pattern. Independent of the precipitation condition (drizzle or rain) and the precipitation rate (high or low), the test temperature played an important role in the result of the comparative test. At -10°C, heat reduced the endurance time of the fluid, whereas at -3°C, it extended the fluid endurance time. The extended endurance time came as a result of the fluid temperature, which had to drop below 0°C in order for the fluid to fail. In the case of the -10°C test, the fluid temperature dropped at subzero temperatures much faster, and consequently the higher dilution rate of the heated fluid became prevalent and led to a shorter endurance time;
- The failure mechanisms described above were not entirely supported by the comparative endurance time testing run with two other fluids. Also, additional data from tests conducted during the 2001-02 winter season showed that the effect of heat did not reduce endurance times. In some cases, a significant improvement was observed; and
- In conclusion, there seems to be a variation among the various fluid types tested, suggesting that perhaps the effect of heat is fluid dependent.

5.2 Endurance Time Testing During Natural Snow

The comparative tests conducted during natural snow conditions indicated that:

- On average, the hot/cold ratio was 85 percent for Type III fluid and 131 percent for Type IV fluid. This indicated that, on average, heating the fluid prior to application resulted in shorter endurance times in the case of less viscous fluids, namely Type III fluids. Also, the effect of heat seems to increase the endurance time of Type IV fluids. These findings match the results from similar tests conducted during the 2001-02 winter season; and
- There also seems to be a difference between the various Type IV fluid types tested, suggesting that perhaps the effect of heat is fluid dependent.

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6. RECOMMENDATIONS

Due to the limited number of tests conducted under both snow and freezing precipitation conditions, and the slightly contradictory results compared with 2001-02 testing, currently there is insufficient data to enable a solid conclusion on the effect of heat on different fluid types and even fluid brands. Therefore, it is recommended that the failure mechanisms be further evaluated and analysed by conducting a new series of comparative tests using different fluid types and dilutions at various temperatures and precipitation rates.

Furthermore, for snow conditions, the application protocol used in 2004-05 was initially developed for Type I fluids. The protocol was empirically developed, by comparing temperature profiles from aircraft wings to those of various test surfaces. However, for these comparative tests, an assumption was made that the correspondence between the aircraft wing profile and the profile of the test surface remains valid when Type IV is used. This assumption will have to be substantiated by conducting a series of comparative tests on the Jetstar wing. These tests should be conducted before further Type IV hot vs. cold tests are run under snow conditions.

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REFERENCES

1. Alwaid, A., Dawson, P., Moc, N., *Generation of Holdover Times Using the New Type I Fluid Test Protocol,* APS Aviation Inc., Transportation Development Centre, Montreal, December 2002, TP 13994E, 106.

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPT – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2003-05

**TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2003-05**

6.19 Effect of Heat on Neat/Diluted Type II/IV Endurance Times

a) Review previous preliminary research that was completed on selected diluted Type II/IV fluids;

b) Design a test protocol with the cooperation of the FAA and TC;

c) Develop a test procedure for testing both outdoors and indoors;

d) Analyse data and results;

e) Prepare a report; and

f) Prepare presentation material.

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APPENDIX B

EXPERIMENTAL PROGRAM:
EFFECT OF HEAT ON ENDURANCE TIME OF ANTI-ICING FLUIDS

CM1892.001 (04-05)

EXPERIMENTAL PROGRAM
EFFECT OF HEAT ON ENDURANCE TIME OF ANTI-ICING FLUIDS
(Subproject: Endurance Time of Non-Aluminum Plates)

Winter 2004-05

Prepared for

Transportation Development Centre
Transport Canada

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Reviewed by: John D'Avirro

APS Aviation Inc.

December 23, 2004
Version 1.0

EXPERIMENTAL PROGRAM
EFFECT OF HEAT ON ENDURANCE TIME OF ANTI-ICING FLUIDS
(Subproject: Endurance Time of Non-Aluminum Plates)

Winter 2004-05

1. BACKGROUND

At an SAE G-12 HOT Subcommittee meeting in November 2000, discussion focused on the need to recognize the contribution of heat in the endurance time test procedure for Type I fluids. Heated Type II and IV fluids at 50/50 and 75/25 concentrations were currently being used in one-step deicing procedures. A motion was made for the test procedure for these fluids to also recognize the contribution of heat and use the same box that is used in tests with the Type I fluids. This is particularly true in European operations.

In 2001-02, preliminary tests were conducted to investigate whether heat significantly influences the endurance times for Type II and Type IV fluids. Five different fluid brands were used for these exploratory tests.

The tests showed that the effect of heat did not reduce endurance times. In some cases, a significant improvement was observed.

Further investigation was recommended.

2. OBJECTIVE

The objective of this research program is to investigate the impact of the test procedure (application method) on endurance time performance. At the same time, the impact of test plate material (non-aluminum) will be explored.

The following are the detailed objectives.

- Effect of heat on Neat and Diluted Type II and Type IV fluid endurance times.
- Effect of heat on Type III fluid (Neat and Diluted) endurance times: currently some operators are considering the use of Type III fluid in the same manner as Type I fluid.

In addition to the previously mentioned objectives, endurance times of fluid on non-aluminum plates will be examined.

The objective of these tests will be to compare the endurance times using the above methods with the endurance times using the standard protocols.

The matrix of outdoor tests is included in Table 1. In addition, a preliminary plan of indoor tests is also included in Table 2.

3. PROCEDURE

Endurance time tests will be conducted with the various fluids at the Dorval airport test site. Standard fluid endurance time test procedures will apply. The tests will be conducted simultaneously following the application methods described below.

3.1 Outdoor Tests with Type II/III/IV Fluids

Position 1: Baseline Standard Test:
1 L of fluid poured (with no spreader) at OAT onto an aluminum plate.

Position 2: Heated Test:
0.5 L of fluid warmed at 60 °C and poured with the warm 12-hole spreader (if fluid is too viscous, then hand pour) onto a box.

Position 3: Non-Aluminum Plate Test:
1 L of fluid poured (with no spreader) at OAT onto a non-aluminum plate.

The summary of these application methods is shown in Figure 1.

Position 1 (Baseline Standard Test)	**Position 2 (Heated Test)**	**Position 3 (Non-Aluminum Plate Test)**
• Plate • 1 L of fluid • Apply at OAT • Poured	• Box (empty) @ OAT • 0.5 L of fluid • Applied at 60 °C • Poured with the 12 hole spreader	• Plate • 1 L of fluid • Apply at OAT • Poured

Figure 1: Position on Stand – Outdoor Tests with Type II/III/IV Fluids

3.2 Indoor Tests Type II/III/IV Fluids

Position 1: Baseline Standard Test:
1 L of fluid poured (with no spreader) at OAT onto an aluminum plate.

Position 2: Heated Test:
1.0 L of fluid warmed at 60 °C and poured with the warm 12-hole spreader (if fluid is too viscous, then hand pour) onto a plate.

Position 3: Non-Aluminum Plate Test:
1 L of fluid poured (with no spreader) at OAT onto a non-aluminum plate.

The summary of these application methods is shown in Figure 2.

Position 1 (Baseline Standard Test)	**Position 2 (Heated Test)**	**Position 3 (Non-Aluminum Plate Test)**
• Plate • 1 L of fluid • Apply at OAT • Poured	• Plate • 1.0 L of fluid • Applied at 60 °C • Poured with the 12 hole spreader	• Plate • 1 L of fluid • Apply at OAT • Poured

Figure 2: Position on Stand – Indoor Tests with Type II/III/IV Fluids

3.3 Outdoor Tests with Type I Fluid

To minimize costs, a non-aluminum box was not developed. Therefore tests shall be conducted on plates as described below.

Position 1: Baseline Standard Test:
1 L of fluid poured at 20°C onto an aluminum plate.

Position 2: Non-Aluminum Plate Test:
1 L of fluid poured at 20°C onto a non-aluminum plate.

The summary of these application methods is shown in Figure 3.

Position 1 (Baseline Standard Test)	Position 2 (Non-Aluminum Plate Test)
• Plate • 1 L of fluid • Apply at 20°C. • Poured • Use 10°C buffer fluid	• Plate • 1 L of fluid • Apply at 20°C • Poured • Use 10°C buffer fluid

Figure 3: Position on Stand – Outdoor Tests with Type I Fluid

3.4 Indoor Tests with Type I Fluid

Position 1: Baseline Standard Test:
1 L of fluid poured at 20°C onto an aluminum plate.

Position 2: Non-Aluminum Plate Test:
1 L of fluid poured at 20°C onto a non-aluminum plate.

The summary of these application methods is shown in Figure 4.

Position 1 (Baseline Standard Test)	Position 2 (Non-Aluminum Plate Test)
• Plate • 1 L of fluid • Apply at 20°C • Poured • Use 10°C buffer fluid	• Plate • 1 L of fluid • Apply at 20°C • Poured • Use 10°C buffer fluid

Figure 4: Position on Stand – Indoor Tests with Type I Fluid

4. FLUIDS

The following fluids (see Table 3) will be used:

- Type III Clariant 2031
- Type I Clariant 1938 PG
- Type IV Dow Ultra+
- Type I Dow EG ADF
- Type IV Kilfrost ABC-S

5. EQUIPMENT

- Logging of temperatures will be required for these tests; and
- Brix measurements and thickness measurements will be needed for a small number of tests.

6. PERSONNEL

Three individuals will be required to conduct these tests. The test manager will measure endurance times. An assistant is required to collect rates and assist with fluid application. A third person is required to prepare the fluids.

7. DATA FORM

The standard endurance time test data forms will be used. To measure fluid Brix and thickness on selected tests, use Table 4.

EXPERIMENTAL PROGRAM: EFFECT OF HEAT ON ENDURANCE TIME OF ANTI-ICNG FLUIDS

TABLE 1: MATRIX OF OUTDOOR TESTS

Test #	Fluid Type	Fluid Brand*	Dilution	Precip Type	Test Temp. [°C]	Precip Rate [g/dm²/h]	STD Test	Heated Box (outdoor)	Non-Aluminum**	Comments
1	III	Clariant 2031	100	Outdoor Snow	any	Any	1	1	1	53 tests were conducted with Type III neat outside, so approx. 5 tests would be reasonable for comparison; various temp and rate conditions
2	III	Clariant 2031	100	Outdoor Snow	any	Any	1	1	1	
3	III	Clariant 2031	100	Outdoor Snow	any	Any	1	1	1	
4	III	Clariant 2031	100	Outdoor Snow	any	Any	1	1		
5	III	Clariant 2031	100	Outdoor Snow	any	Any	1	1		
6	III	Clariant 2031	75	Outdoor Snow	>-14°C	Any	1	1	1	
7	III	Clariant 2031	75	Outdoor Snow	>-14°C	Any	1	1	1	
8	III	Clariant 2031	75	Outdoor Snow	>-14°C	Any	1	1	1	
9	III	Clariant 2031	75	Outdoor Snow	>-14°C	Any	1	1		
10	III	Clariant 2031	75	Outdoor Snow	>-14°C	Any	1	1		
11	III	Clariant 2031	75	Outdoor Snow	>-14°C	Any	1	1		
12	III	Clariant 2031	75	Outdoor Snow	>-14°C	Any	1	1		
13	III	Clariant 2031	50	Outdoor Snow	>-3°C	Any	1	1	1	
14	III	Clariant 2031	50	Outdoor Snow	>-3°C	Any	1	1	1	
15	III	Clariant 2031	50	Outdoor Snow	>-3°C	Any	1	1	1	
16	III	Clariant 2031	50	Outdoor Snow	>-3°C	Any	1	1		
17	III	Clariant 2031	50	Outdoor Snow	>-3°C	Any	1	1		
18	IV	Dow Ultra +	100	Outdoor Snow	any	Any	1	1	1	
19	IV	Dow Ultra +	100	Outdoor Snow	any	Any	1	1	1	
20	IV	Dow Ultra +	100	Outdoor Snow	any	Any	1	1	1	
21	IV	Dow Ultra +	100	Outdoor Snow	any	Any	1	1	1	
22	IV	Dow Ultra +	100	Outdoor Snow	any	Any	1	1	1	
23	IV	Dow Ultra +	100	Outdoor Snow	any	Any	1	1	1	
24	IV	Dow Ultra +	100	Outdoor Snow	any	Any	1	1	1	
25	II,III, IV	Product A (new)	100	Outdoor Snow	any	Any	1	1	1	
26	II,III, IV	Product A (new)	100	Outdoor Snow	any	Any	1	1	1	
27	II,III, IV	Product A (new)	100	Outdoor Snow	any	Any	1	1	1	
28	II,III, IV	Product A (new)	75	Outdoor Snow	>-14°C	Any	1	1	1	
29	II,III, IV	Product A (new)	75	Outdoor Snow	>-14°C	Any	1	1	1	
30	II,III, IV	Product A (new)	50	Outdoor Snow	>-3°C	Any	1	1	1	
31	II,III, IV	Product A (new)	50	Outdoor Snow	>-3°C	Any	1	1	1	
32	II,III, IV	Product B (new)	100	Outdoor Snow	any	Any	1	1	NR for Prod B	
33	II,III, IV	Product B (new)	100	Outdoor Snow	any	Any	1	1	NR for Prod B	
34	II,III, IV	Product B (new)	100	Outdoor Snow	any	Any	1	1	NR for Prod B	
35	II,III, IV	Product B (new)	75	Outdoor Snow	>-14°C	Any	1	1	NR for Prod B	
36	II,III, IV	Product B (new)	75	Outdoor Snow	>-14°C	Any	1	1	NR for Prod B	
37	II,III, IV	Product B (new)	50	Outdoor Snow	>-3°C	Any	1	1	NR for Prod B	
38	II,III, IV	Product B (new)	50	Outdoor Snow	>-3°C	Any	1	1	NR for Prod B	
39	II,III, IV	Product C (new)	100	Outdoor Snow	any	Any	1	1	1	
40	II,III, IV	Product C (new)	100	Outdoor Snow	any	Any	1	1	1	
41	II,III, IV	Product C (new)	100	Outdoor Snow	any	Any	1	1	1	
42	II,III, IV	Product C (new)	75	Outdoor Snow	>-14°C	Any	1	1	1	
43	II,III, IV	Product C (new)	75	Outdoor Snow	>-14°C	Any	1	1	1	
44	II,III, IV	Product C (new)	50	Outdoor Snow	>-3°C	Any	1	1	1	
45	II,III, IV	Product C (new)	50	Outdoor Snow	>-3°C	Any	1	1	1	
46	II,III, IV	Product D (new)	100	Outdoor Snow	any	Any	1	1	NR for Prod D	
47	II,III, IV	Product D (new)	100	Outdoor Snow	any	Any	1	1	NR for Prod D	
48	II,III, IV	Product D (new)	100	Outdoor Snow	any	Any	1	1	NR for Prod D	
49	II,III, IV	Product D (new)	75	Outdoor Snow	>-14°C	Any	1	1	NR for Prod D	
50	II,III, IV	Product D (new)	75	Outdoor Snow	>-14°C	Any	1	1	NR for Prod D	
51	II,III, IV	Product D (new)	50	Outdoor Snow	>-3°C	Any	1	1	NR for Prod D	
52	II,III, IV	Product D (new)	50	Outdoor Snow	>-3°C	Any	1	1	NR for Prod D	
53	IV	Kilfrost ABC-S	100	Outdoor Snow	any	Any	1	1	1	
54	IV	Kilfrost ABC-S	100	Outdoor Snow	any	Any	1	1	1	
55	IV	Kilfrost ABC-S	100	Outdoor Snow	any	Any	1	1	1	
56	IV	Kilfrost ABC-S	75	Outdoor Snow	>-14°C	Any	1	1	1	
57	IV	Kilfrost ABC-S	75	Outdoor Snow	>-14°C	Any	1	1	1	
58	IV	Kilfrost ABC-S	50	Outdoor Snow	>-3°C	Any	1	1	1	
59	IV	Kilfrost ABC-S	50	Outdoor Snow	>-3°C	Any	1	1	1	
60	I	Dow EG ADF	10 Deg B	Outdoor Snow	any	Any	1		1	For STD/non-al test apply fluid @ 20C not OAT
61	I	Dow EG ADF	10 Deg B	Outdoor Snow	any	Any	1		1	For STD/non-al test apply fluid @ 20C not OAT
62	I	Dow EG ADF	10 Deg B	Outdoor Snow	any	Any	1		1	For STD/non-al test apply fluid @ 20C not OAT
63	I	Clariant 1938 PG	10 Deg B	Outdoor Snow	any	Any	1		1	For STD/non-al test apply fluid @ 20C not OAT
64	I	Clariant 1938 PG	10 Deg B	Outdoor Snow	any	Any	1		1	For STD/non-al test apply fluid @ 20C not OAT
65	I	Clariant 1938 PG	10 Deg B	Outdoor Snow	any	Any	1		1	For STD/non-al test apply fluid @ 20C not OAT

*** Note that if a new product A, B, C or D is a Type III, then this could be used for testing for one of these sets of tests.**
**** Note that tests that do not have non-aluminum plates are lower priority.**

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EXPERIMENTAL PROGRAM: EFFECT OF HEAT ON ENDURANCE TIME OF ANTI-ICNG FLUIDS

TABLE 2: MATRIX OF INDOOR TESTS

Test #	Fluid Type	Fluid Brand*	Dilution	Precip Type	Test Temp. [°C]	Precip Rate [g/dm²/h]	STD Test	Non-Aluminum**	Heated Plate (indoor)	Comments
101	III	Clariant 2031	100	ZD	-3	TBD	1	1	1	TBD after outdoor tests
102	III	Clariant 2031	75	ZD	-3	TBD	1	1	1	TBD after outdoor tests
103	III	Clariant 2031	50	ZD	-3	TBD	1	1	1	TBD after outdoor tests
104	III	Clariant 2031	100	ZR	-3	TBD	1	1	1	TBD after outdoor tests
105	III	Clariant 2031	75	ZR	-3	TBD	1	1	1	TBD after outdoor tests
106	III	Clariant 2031	50	ZR	-3	TBD	1	1	1	TBD after outdoor tests
107	III	Clariant 2031	100	ZD	-10	TBD	1	1	1	TBD after outdoor tests
108	III	Clariant 2031	75	ZD	-10	TBD	1	1	1	TBD after outdoor tests
109	III	Clariant 2031	100	ZR	-10	TBD	1	1	1	TBD after outdoor tests
110	III	Clariant 2031	75	ZR	-10	TBD	1	1	1	TBD after outdoor tests
111	IV	Dow Ultra +	100	ZD	-3	TBD	1	1	1	TBD after outdoor tests
112	IV	Dow Ultra +	100	ZR	-3	TBD	1	1	1	TBD after outdoor tests
113	IV	Dow Ultra +	100	ZD	-10	TBD	1	1	1	TBD after outdoor tests
114	IV	Dow Ultra +	100	ZR	-10	TBD	1	1	1	TBD after outdoor tests
115	II,III, IV	Product A (new)	100	ZD	-3	TBD	1	1	1	TBD after outdoor tests
116	II,III, IV	Product A (new)	100	ZR	-3	TBD	1	1	1	TBD after outdoor tests
117	II,III, IV	Product A (new)	100	ZD	-10	TBD	1	1	1	TBD after outdoor tests
118	II,III, IV	Product A (new)	100	ZR	-10	TBD	1	1	1	TBD after outdoor tests
119	II,III, IV	Product A (new)	75	ZD	-3	TBD	1	1	1	TBD after outdoor tests
120	II,III, IV	Product A (new)	75	ZR	-3	TBD	1	1	1	TBD after outdoor tests
121	II,III, IV	Product A (new)	75	ZD	-10	TBD	1	1	1	TBD after outdoor tests
122	II,III, IV	Product A (new)	75	ZR	-10	TBD	1	1	1	TBD after outdoor tests
123	II,III, IV	Product A (new)	50	ZD	-3	TBD	1	1	1	TBD after outdoor tests
124	II,III, IV	Product A (new)	50	ZR	-3	TBD	1	1	1	TBD after outdoor tests
125	II,III, IV	Product B (new)	100	ZD	-3	TBD	1	NR for Prod B	1	TBD after outdoor tests
126	II,III, IV	Product B (new)	100	ZR	-3	TBD	1	NR for Prod B	1	TBD after outdoor tests
127	II,III, IV	Product B (new)	100	ZD	-10	TBD	1	NR for Prod B	1	TBD after outdoor tests
128	II,III, IV	Product B (new)	100	ZR	-10	TBD	1	NR for Prod B	1	TBD after outdoor tests
129	II,III, IV	Product B (new)	75	ZD	-3	TBD	1	NR for Prod B	1	TBD after outdoor tests
130	II,III, IV	Product B (new)	75	ZR	-3	TBD	1	NR for Prod B	1	TBD after outdoor tests
131	II,III, IV	Product B (new)	75	ZD	-10	TBD	1	NR for Prod B	1	TBD after outdoor tests
132	II,III, IV	Product B (new)	75	ZR	-10	TBD	1	NR for Prod B	1	TBD after outdoor tests
133	II,III, IV	Product B (new)	50	ZD	-3	TBD	1	NR for Prod B	1	TBD after outdoor tests
134	II,III, IV	Product B (new)	50	ZR	-3	TBD	1	NR for Prod B	1	TBD after outdoor tests
135	II,III, IV	Product C (new)	100	ZD	-3	TBD	1	1	1	TBD after outdoor tests
136	II,III, IV	Product C (new)	100	ZR	-3	TBD	1	1	1	TBD after outdoor tests
137	II,III, IV	Product C (new)	100	ZD	-10	TBD	1	1	1	TBD after outdoor tests
138	II,III, IV	Product C (new)	100	ZR	-10	TBD	1	1	1	TBD after outdoor tests
139	II,III, IV	Product C (new)	75	ZD	-3	TBD	1	1	1	TBD after outdoor tests
140	II,III, IV	Product C (new)	75	ZR	-3	TBD	1	1	1	TBD after outdoor tests
141	II,III, IV	Product C (new)	75	ZD	-10	TBD	1	1	1	TBD after outdoor tests
142	II,III, IV	Product C (new)	75	ZR	-10	TBD	1	1	1	TBD after outdoor tests
143	II,III, IV	Product C (new)	50	ZD	-3	TBD	1	1	1	TBD after outdoor tests
144	II,III, IV	Product C (new)	50	ZR	-3	TBD	1	1	1	TBD after outdoor tests
145	II,III, IV	Product D (new)	100	ZD	-3	TBD	1	NR for Prod D	1	TBD after outdoor tests
146	II,III, IV	Product D (new)	100	ZR	-3	TBD	1	NR for Prod D	1	TBD after outdoor tests
147	II,III, IV	Product D (new)	100	ZD	-10	TBD	1	NR for Prod D	1	TBD after outdoor tests
148	II,III, IV	Product D (new)	100	ZR	-10	TBD	1	NR for Prod D	1	TBD after outdoor tests
149	II,III, IV	Product D (new)	75	ZD	-3	TBD	1	NR for Prod D	1	TBD after outdoor tests
150	II,III, IV	Product D (new)	75	ZR	-3	TBD	1	NR for Prod D	1	TBD after outdoor tests
151	II,III, IV	Product D (new)	75	ZD	-10	TBD	1	NR for Prod D	1	TBD after outdoor tests
152	II,III, IV	Product D (new)	75	ZR	-10	TBD	1	NR for Prod D	1	TBD after outdoor tests
153	II,III, IV	Product D (new)	50	ZD	-3	TBD	1	NR for Prod D	1	TBD after outdoor tests
154	II,III, IV	Product D (new)	50	ZR	-3	TBD	1	NR for Prod D	1	TBD after outdoor tests
155	IV	Kilfrost ABC-S	100	ZD	-3	TBD	1	1	1	TBD after outdoor tests
156	IV	Kilfrost ABC-S	100	ZR	-3	TBD	1	1	1	TBD after outdoor tests
157	IV	Kilfrost ABC-S	100	ZD	-10	TBD	1	1	1	TBD after outdoor tests
158	IV	Kilfrost ABC-S	100	ZR	-10	TBD	1	1	1	TBD after outdoor tests
159	IV	Kilfrost ABC-S	75	ZD	-3	TBD	1	1	1	TBD after outdoor tests
160	IV	Kilfrost ABC-S	75	ZR	-3	TBD	1	1	1	TBD after outdoor tests
161	IV	Kilfrost ABC-S	75	ZD	-10	TBD	1	1	1	TBD after outdoor tests
162	IV	Kilfrost ABC-S	75	ZR	-10	TBD	1	1	1	TBD after outdoor tests
163	IV	Kilfrost ABC-S	50	ZD	-3	TBD	1	1	1	TBD after outdoor tests
164	IV	Kilfrost ABC-S	50	ZR	-3	TBD	1	1	1	TBD after outdoor tests
165	I	Dow EG ADF	10 Deg B	ZD	-3	TBD	1	1		For STD/non-al test apply fluid @ 20C not OAT
166	I	Dow EG ADF	10 Deg B	ZD	-10	TBD	1	1		For STD/non-al test apply fluid @ 20C not OAT
167	I	Dow EG ADF	10 Deg B	ZR	-10	TBD	1	1		For STD/non-al test apply fluid @ 20C not OAT
168	I	Clariant 1938 PG	10 Deg B	ZD	-3	TBD	1	1		For STD/non-al test apply fluid @ 20C not OAT
169	I	Clariant 1938 PG	10 Deg B	ZD	-10	TBD	1	1		For STD/non-al test apply fluid @ 20C not OAT
170	I	Clariant 1938 PG	10 Deg B	ZR	-10	TBD	1	1		For STD/non-al test apply fluid @ 20C not OAT

* Note that if a new product A, B, C or D is a Type III, then this could be used for testing for one of these sets of tests.
** Note that tests that do not have non-aluminum plates are lower priority.

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Version 1.0, December 2004

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**TABLE 3: LIST OF FLUIDS NEEDED
(NON-ALUMINUM, HEATED TYPE III, HEATED TYPE II/IV)**

Fluid	Dilution	Quantity Needed	Batch No. (Location)		Comments/Location
Clariant 2031	100	15 L	TV390 (25)		
	75	20 L	TV390 (23)		
	50	10 L	TV390 (24)		
Ultra +	100	20 L	QI13555D2(23)		Barrel
Clariant 1938 Type I		9 L	TV363 (34)		
UCAR EG Type I		9 L	TV363 (34)		Need to locate
ABC-S	100	9 L	13402 (30)		Shed
	75	6 L			
	50	6 L			

TABLE 4: FLUID BRIX/THICKNESS DATA FORM

DATE: _______________ PERFORMED BY: _______________

RUN #: _______________ WRITTEN BY: _______________

STAND: _______________ LOCATION: _______________

Plate / BOX: Fluid:			Plate / BOX: Fluid:			Plate / BOX: Fluid:		
TIME	Brix at 15 cm Line	Thick. at 15 cm Line	TIME	Brix at 15 cm Line	Thick. at 15 cm Line	TIME	Brix at 15 cm Line	Thick. at 15 cm Line

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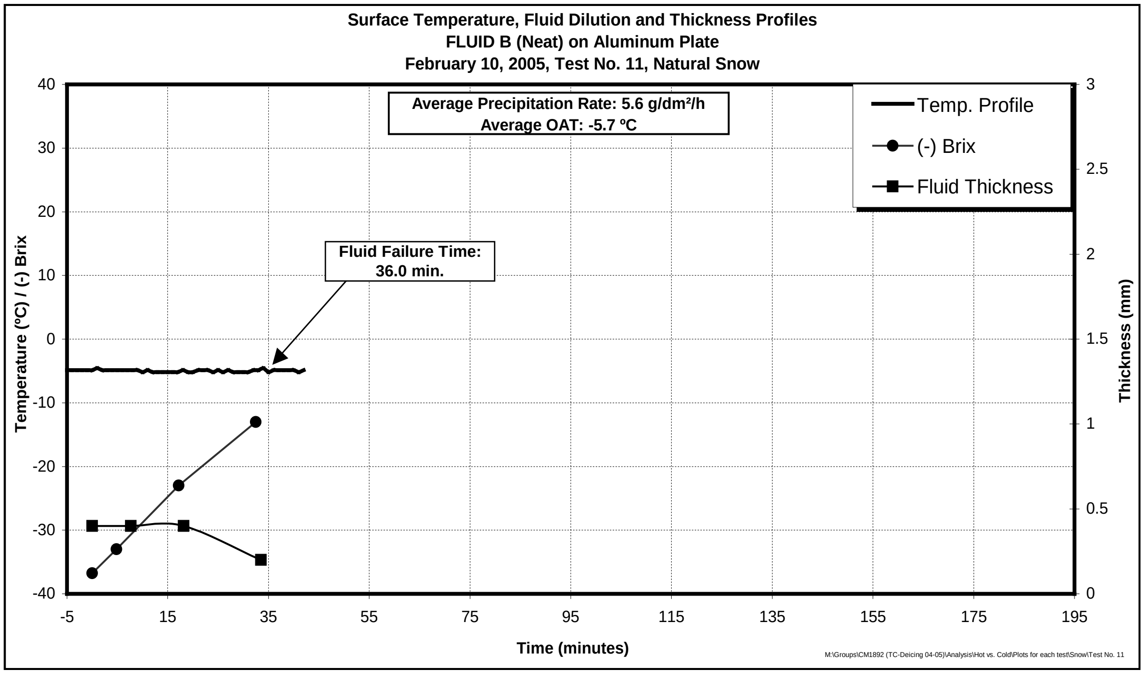
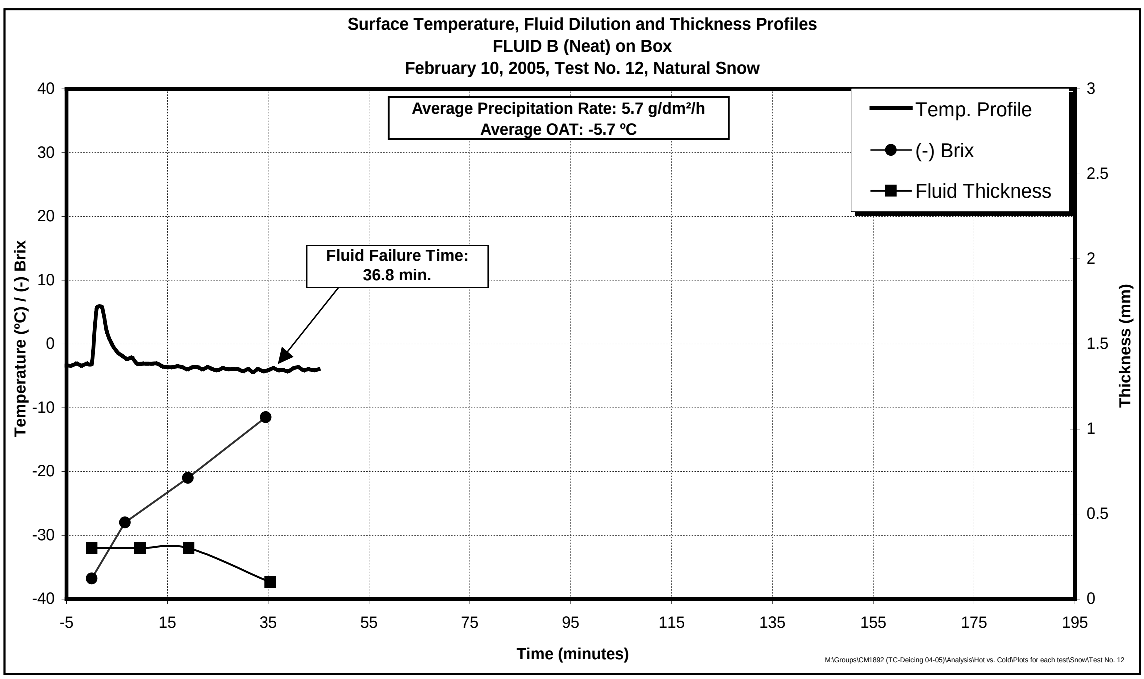
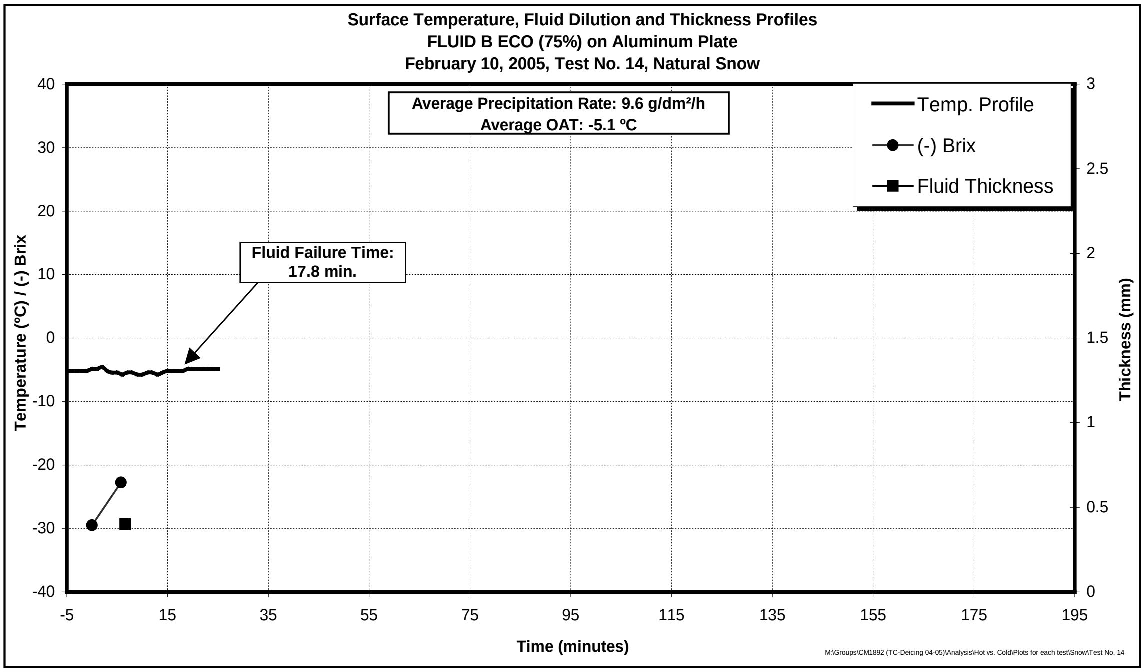
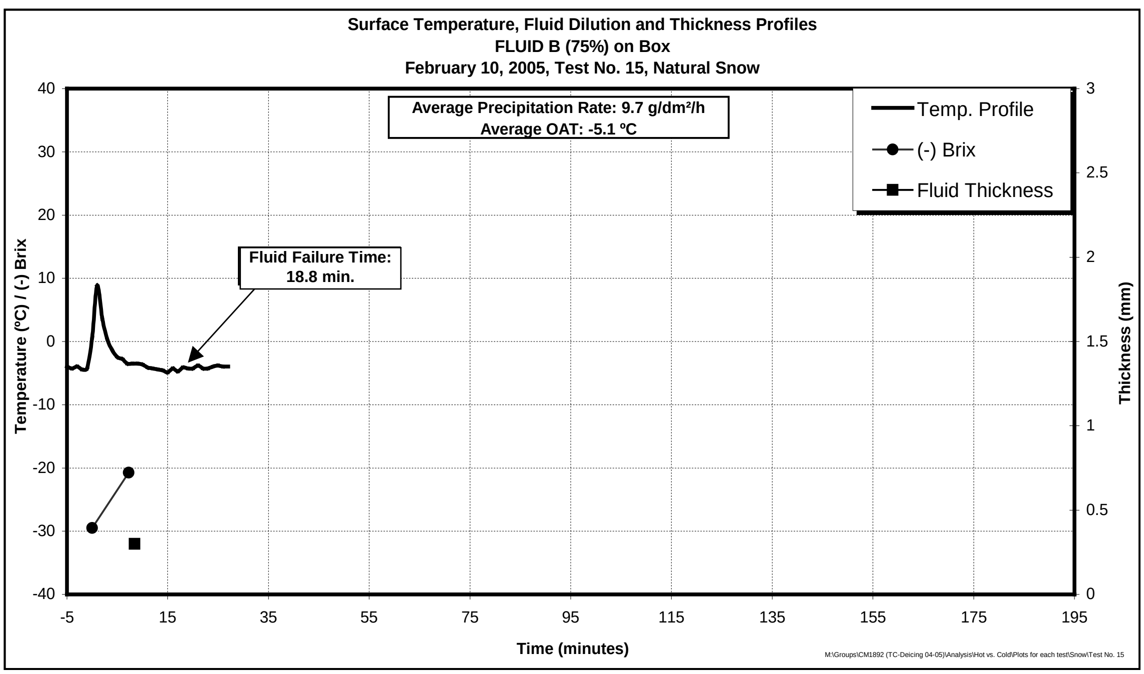
APPENDIX C

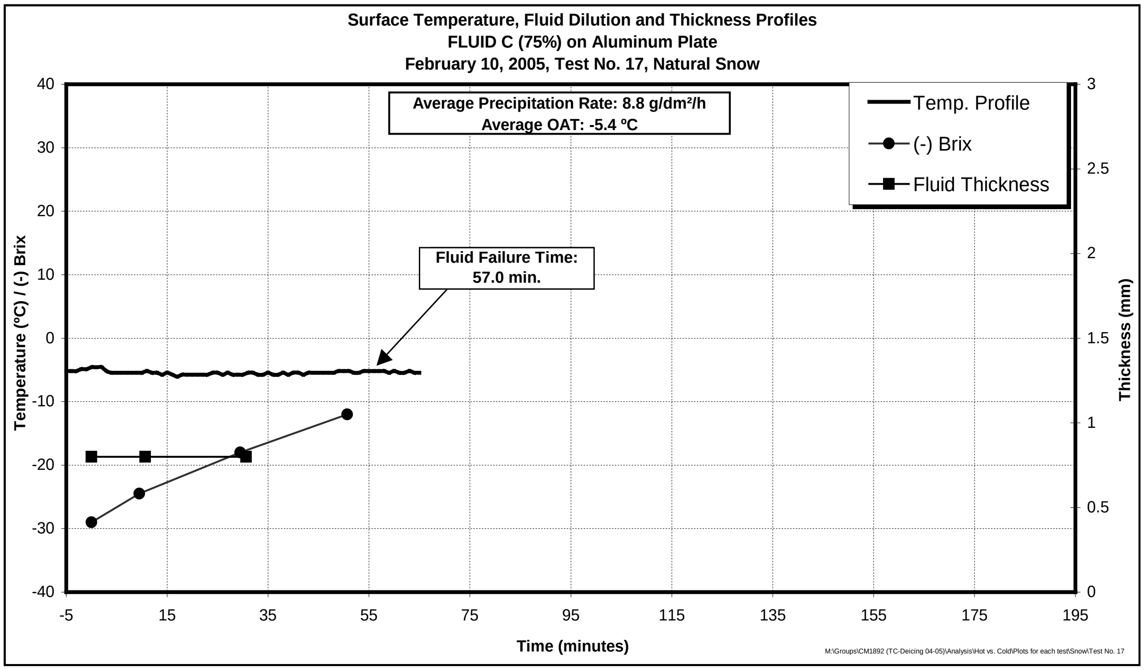
DETAILED CHARTS OF ENDURANCE TIME COMPARISON TESTS

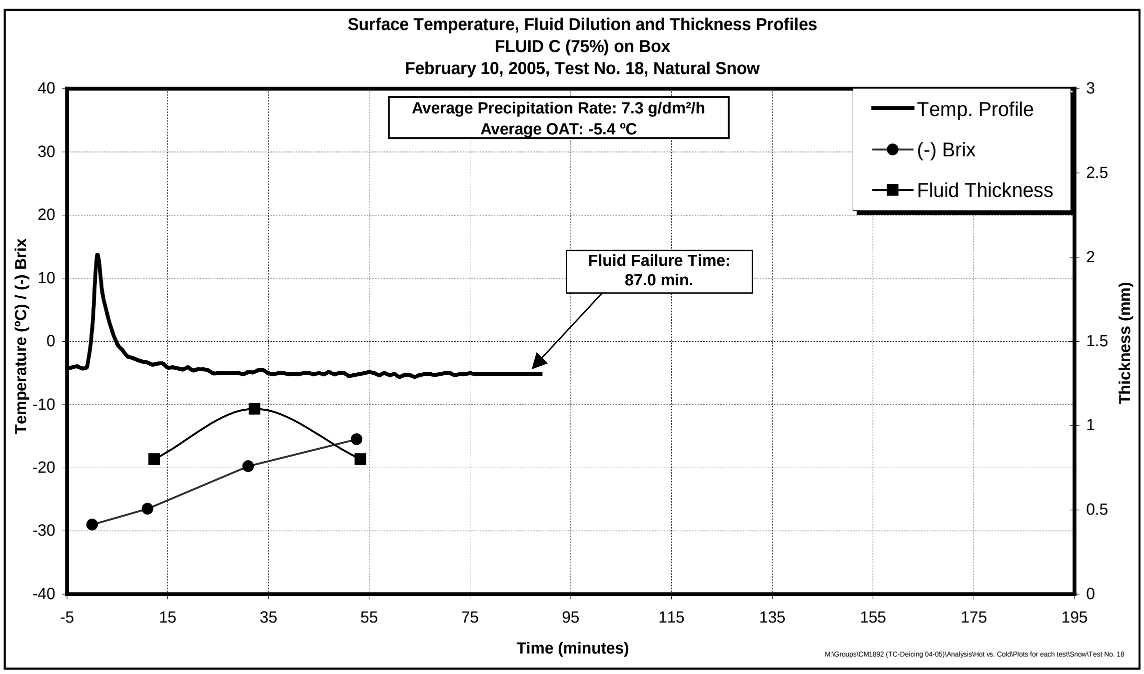

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Aluminum Plate
February 10, 2005, Test No. 11, Natural Snow
Average Precipitation Rate: 5.6 g/dm²/h
Average OAT: -5.7 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
36.0 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

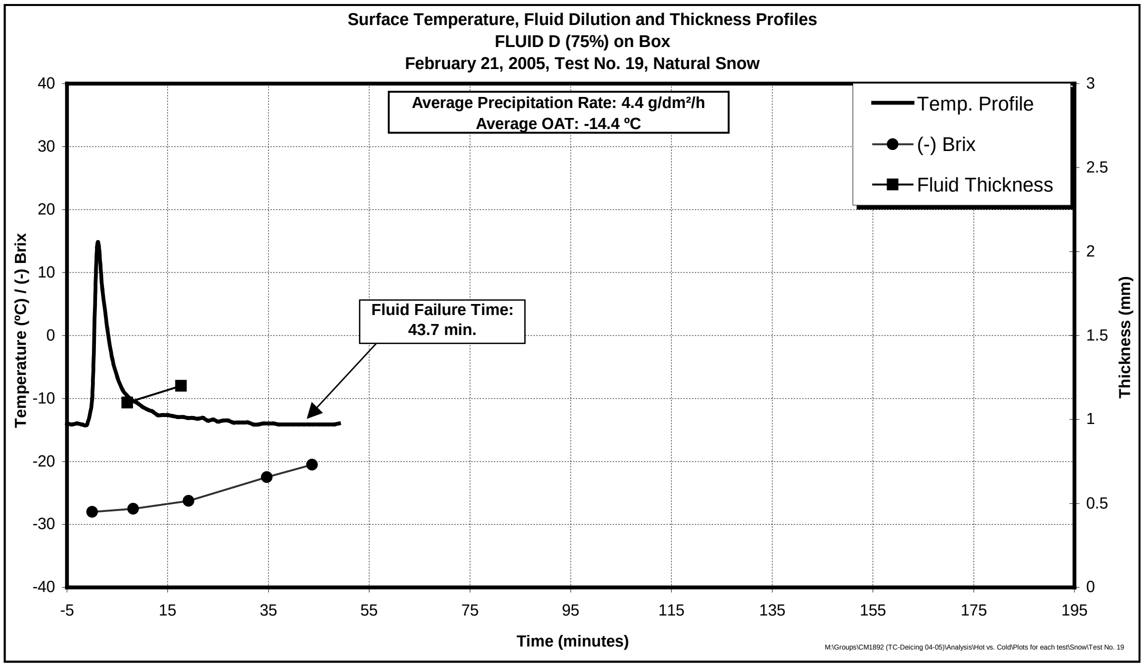

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Box
February 10, 2005, Test No. 12, Natural Snow
Average Precipitation Rate: 5.7 g/dm²/h
Average OAT: -5.7 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
36.8 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B ECO (75%) on Aluminum Plate
February 10, 2005, Test No. 14, Natural Snow
Average Precipitation Rate: 9.6 g/dm²/h
Average OAT: -5.1 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
17.8 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

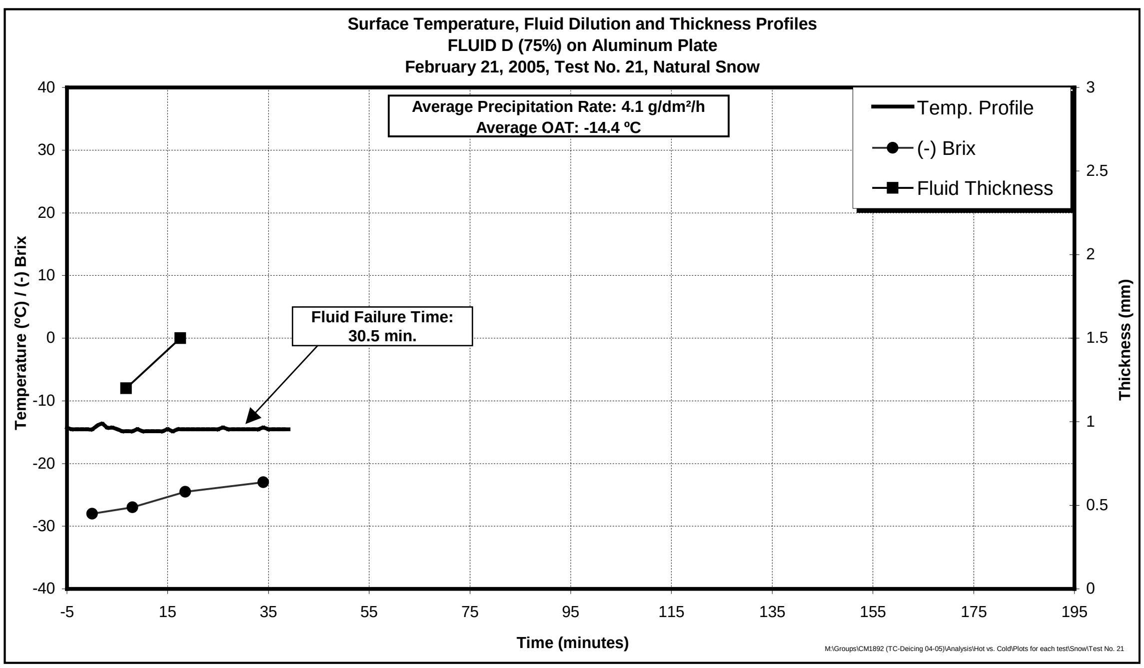

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Box
February 10, 2005, Test No. 15, Natural Snow
Average Precipitation Rate: 9.7 g/dm²/h
Average OAT: -5.1 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
18.8 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Aluminum Plate
February 10, 2005, Test No. 17, Natural Snow
Average Precipitation Rate: 8.8 g/dm²/h
Average OAT: -5.4 ºC
Fluid Failure Time:
57.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

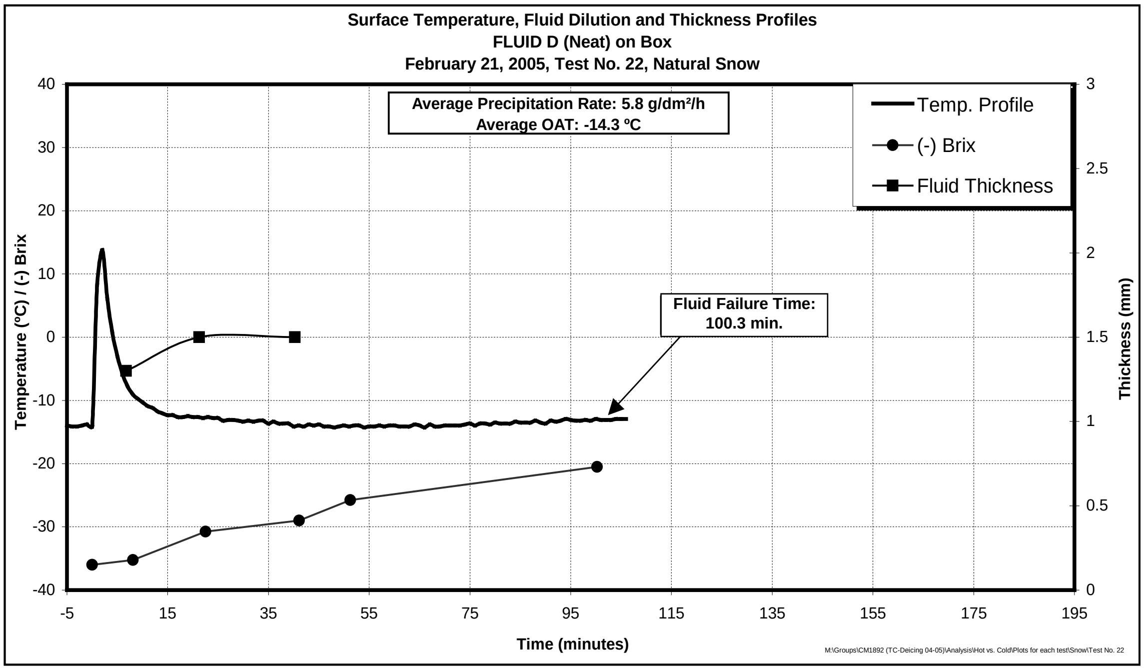

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Box
February 10, 2005, Test No. 18, Natural Snow
Average Precipitation Rate: 7.3 g/dm²/h
Average OAT: -5.4 ºC
Fluid Failure Time:
87.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

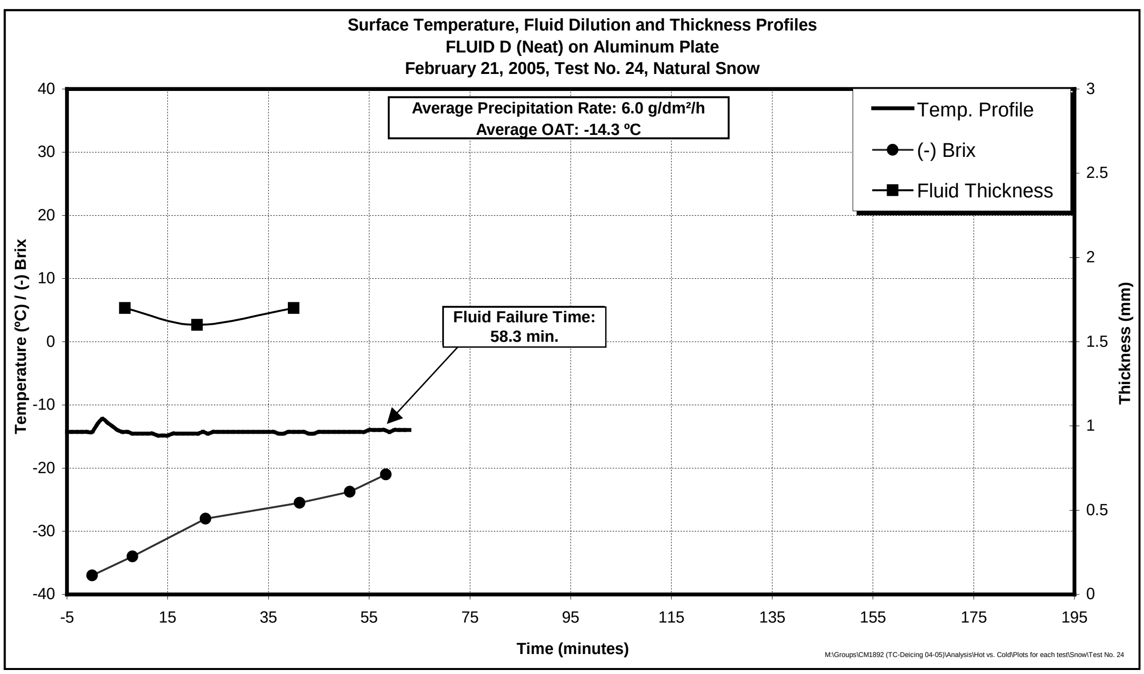


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (75%) on Box
February 21, 2005, Test No. 19, Natural Snow
Average Precipitation Rate: 4.4 g/dm²/h
Average OAT: -14.4 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
43.7 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195



Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (75%) on Aluminum Plate
February 21, 2005, Test No. 21, Natural Snow
Average Precipitation Rate: 4.1 g/dm²/h
Average OAT: -14.4 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
30.5 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (Neat) on Box
February 21, 2005, Test No. 22, Natural Snow
Average Precipitation Rate: 5.8 g/dm²/h
Average OAT: -14.3 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
100.3 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Snow\Test No. 22


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (Neat) on Aluminum Plate
February 21, 2005, Test No. 24, Natural Snow
Average Precipitation Rate: 6.0 g/dm²/h
Average OAT: -14.3 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
58.3 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
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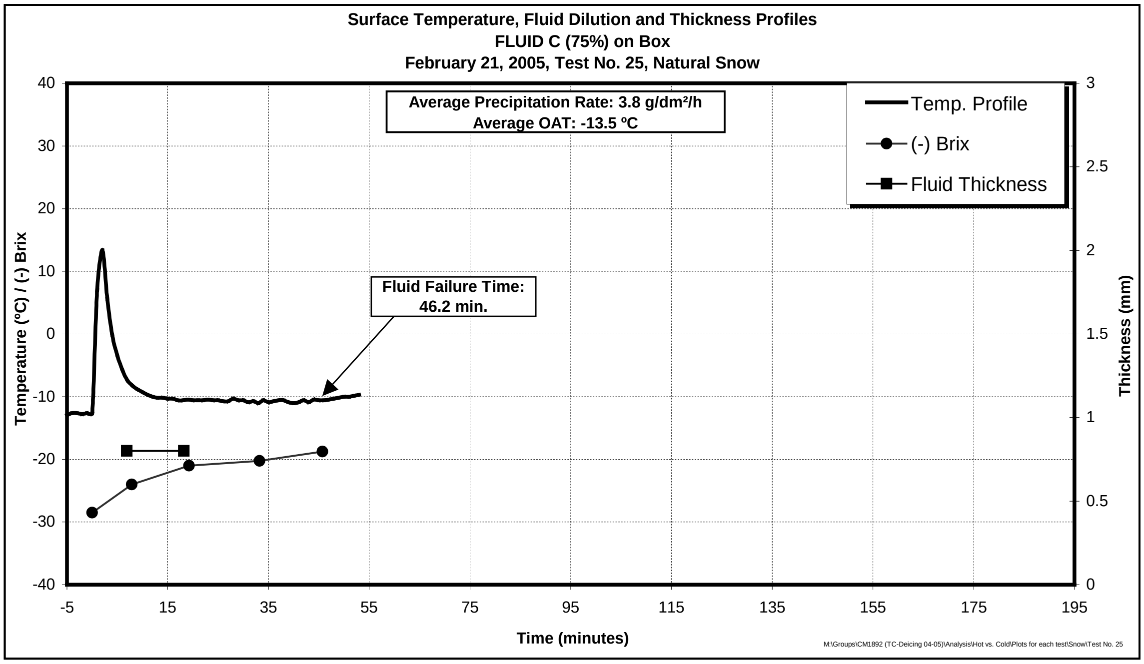
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Box
February 21, 2005, Test No. 25, Natural Snow
Average Precipitation Rate: 3.8 g/dm²/h
Average OAT: -13.5 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
46.2 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
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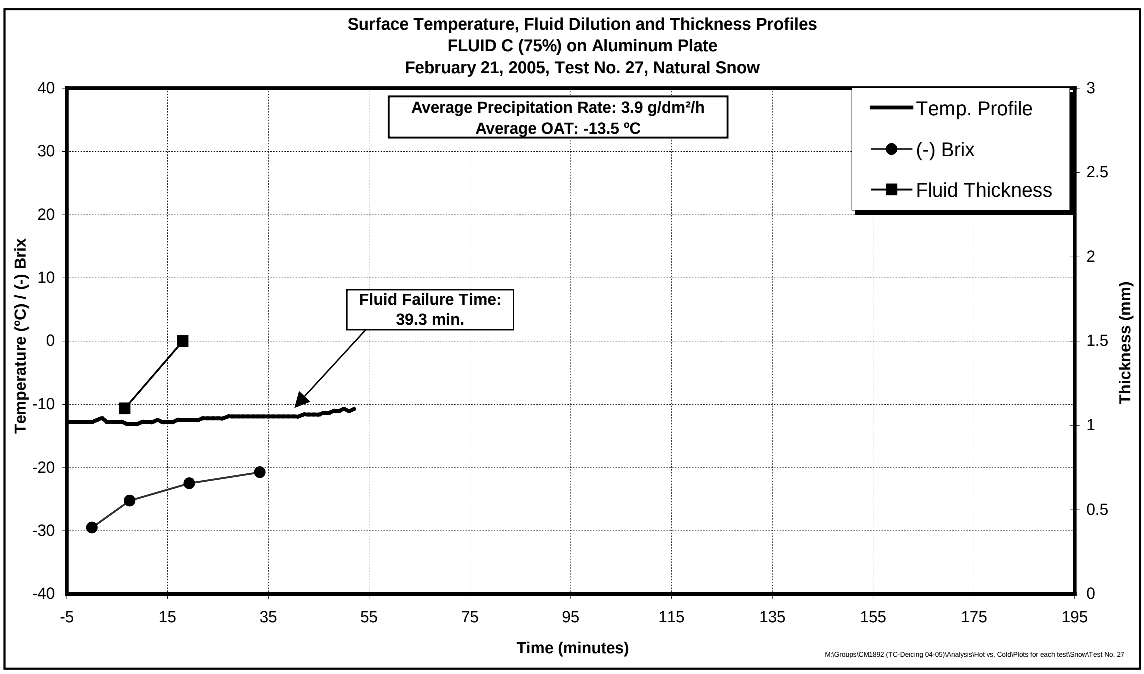
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Aluminum Plate
February 21, 2005, Test No. 27, Natural Snow
Average Precipitation Rate: 3.9 g/dm²/h
Average OAT: -13.5 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
39.3 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
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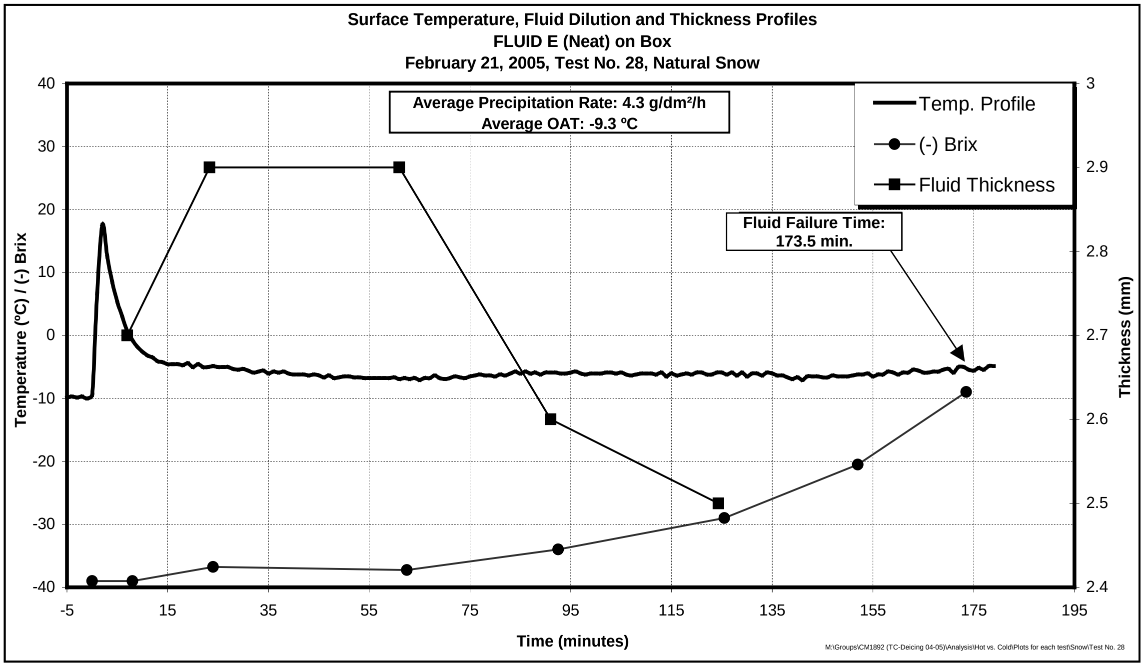
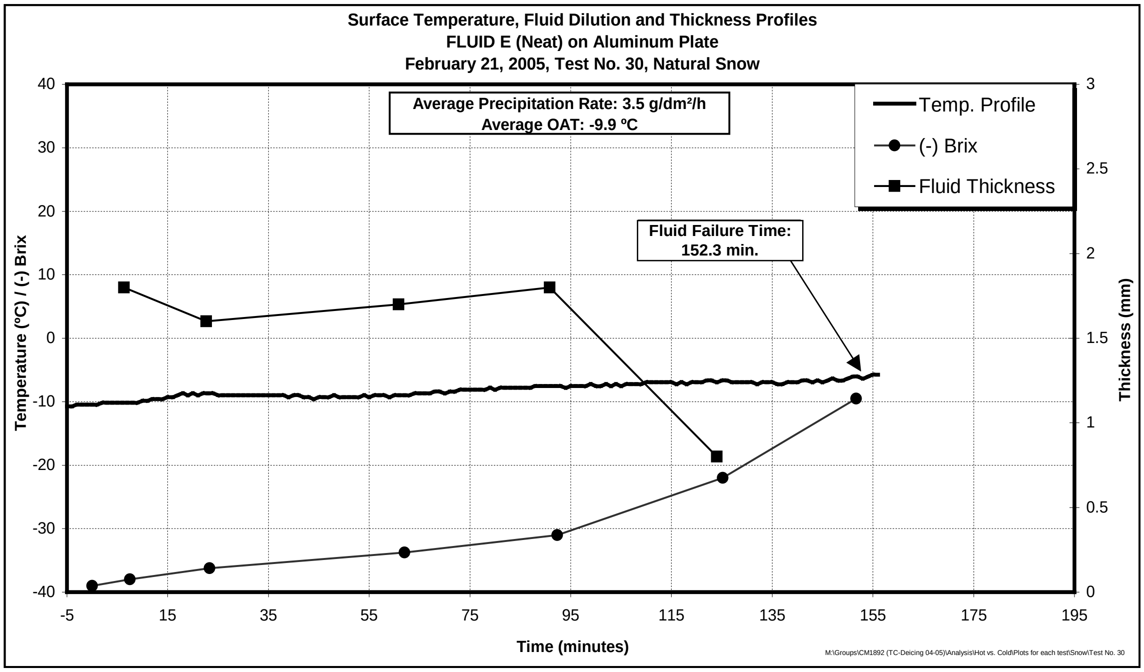
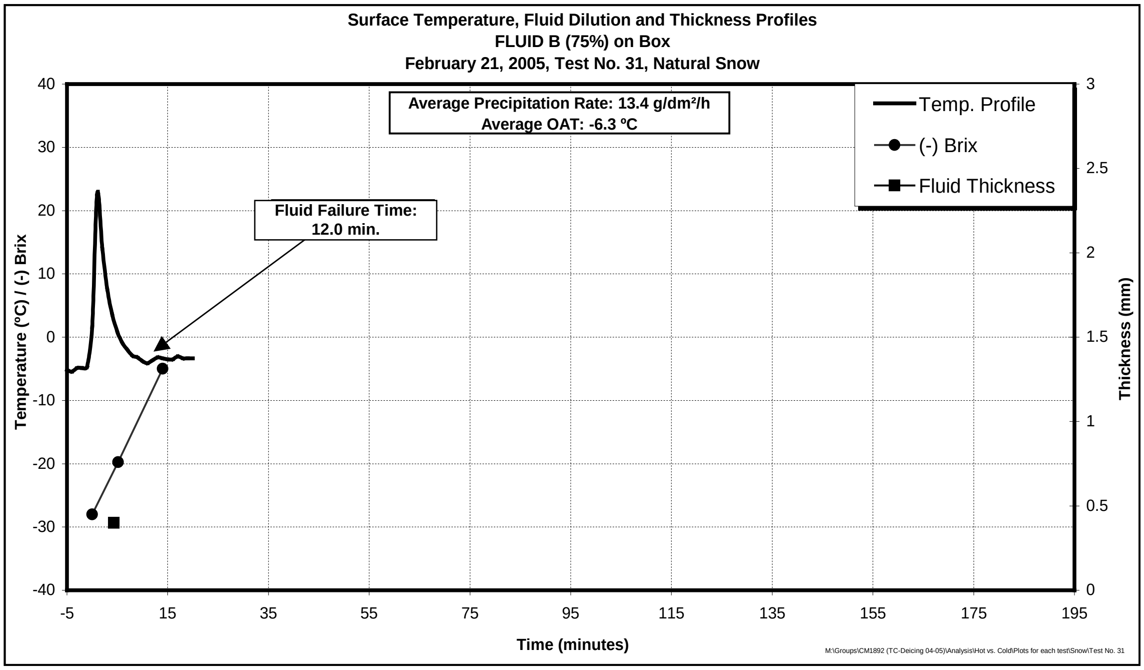
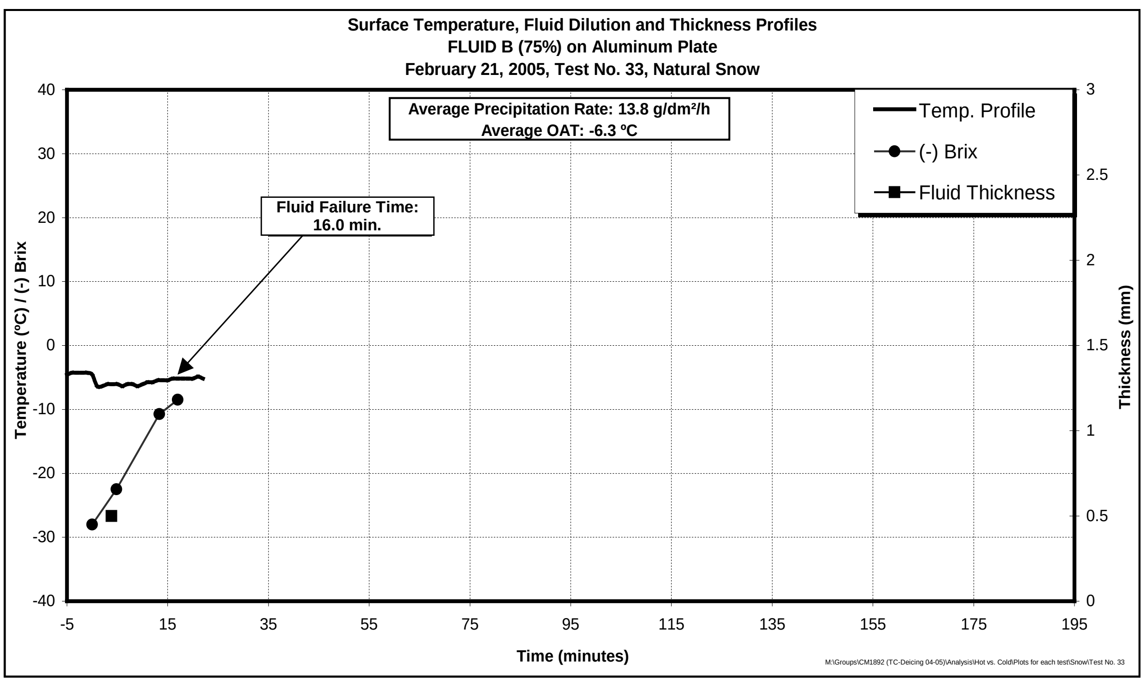
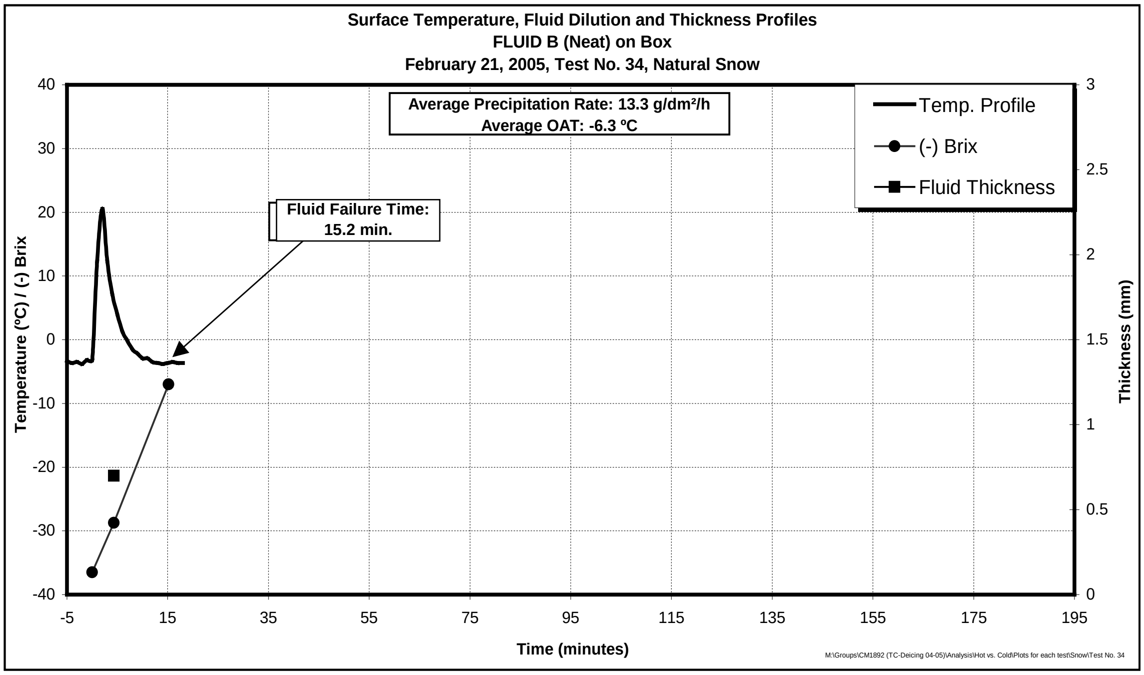
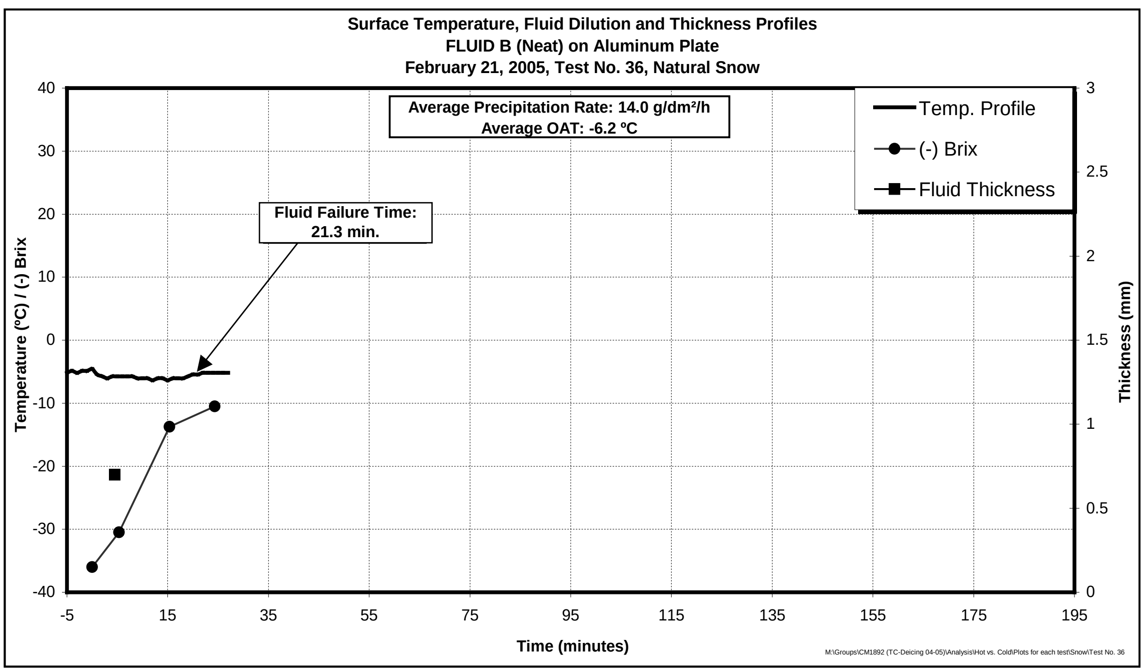

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID E (Neat) on Box
February 21, 2005, Test No. 28, Natural Snow
Average Precipitation Rate: 4.3 g/dm²/h
Average OAT: -9.3 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
173.5 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.9
2.8
2.7
2.6
2.5
2.4
-5
15
35
55
75
95
115
135
155
175
195

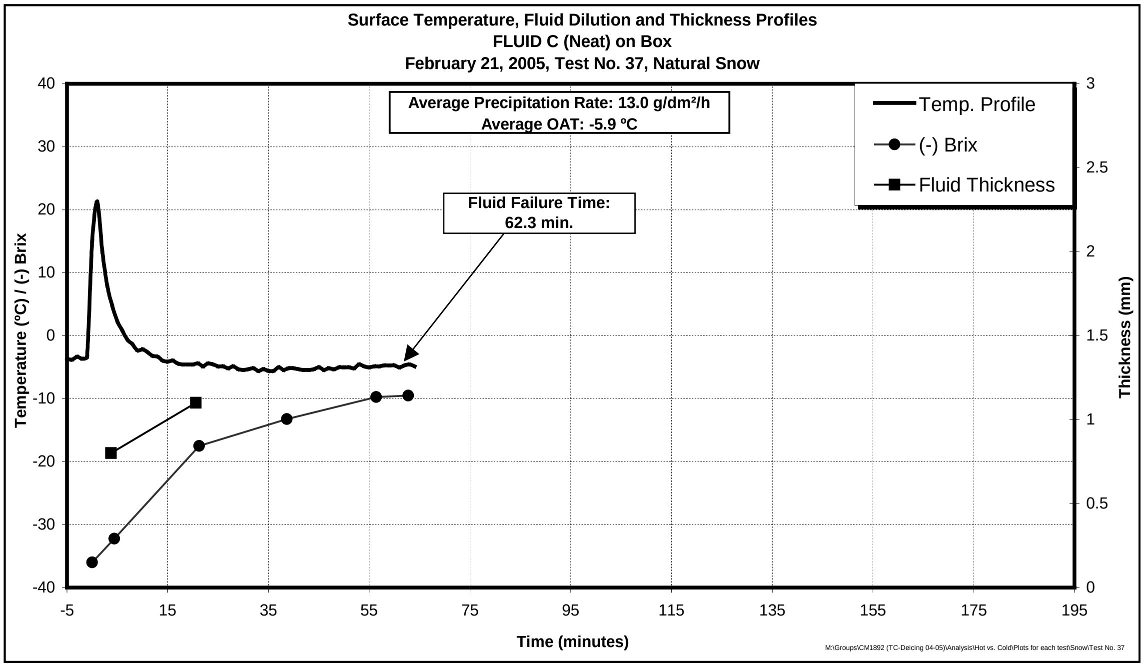

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID E (Neat) on Aluminum Plate
February 21, 2005, Test No. 30, Natural Snow
Average Precipitation Rate: 3.5 g/dm²/h
Average OAT: -9.9 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
152.3 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

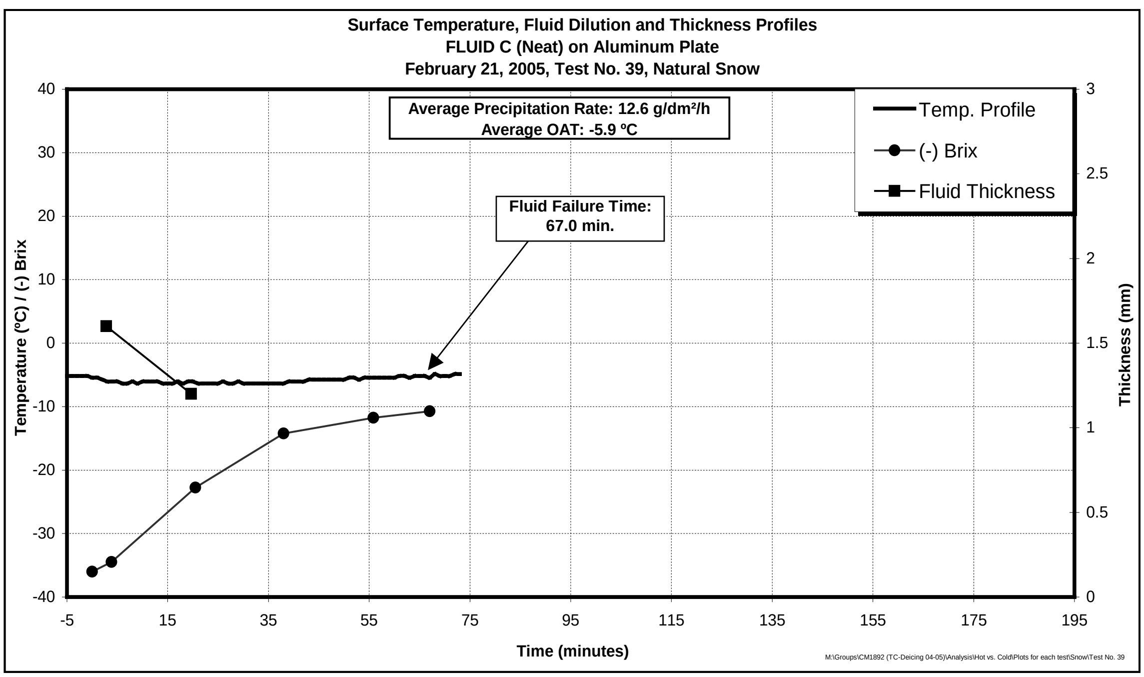

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Box
February 21, 2005, Test No. 31, Natural Snow
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -6.3 ºC
Fluid Failure Time:
12.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0

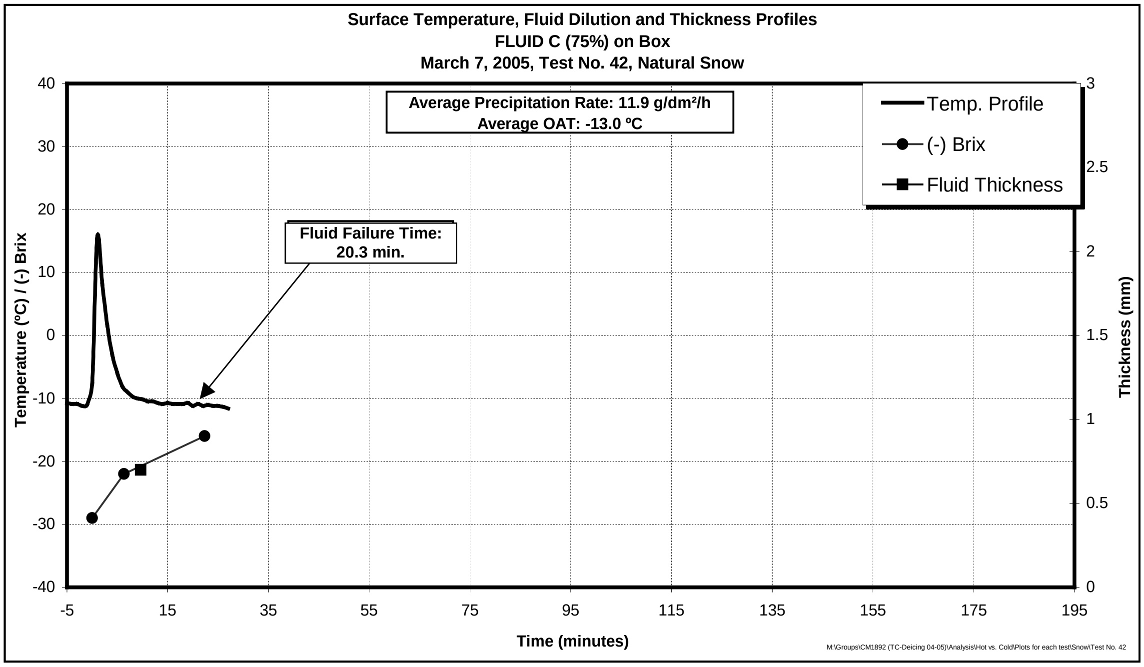

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
February 21, 2005, Test No. 33, Natural Snow
Average Precipitation Rate: 13.8 g/dm²/h
Average OAT: -6.3 ºC
Fluid Failure Time:
16.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0

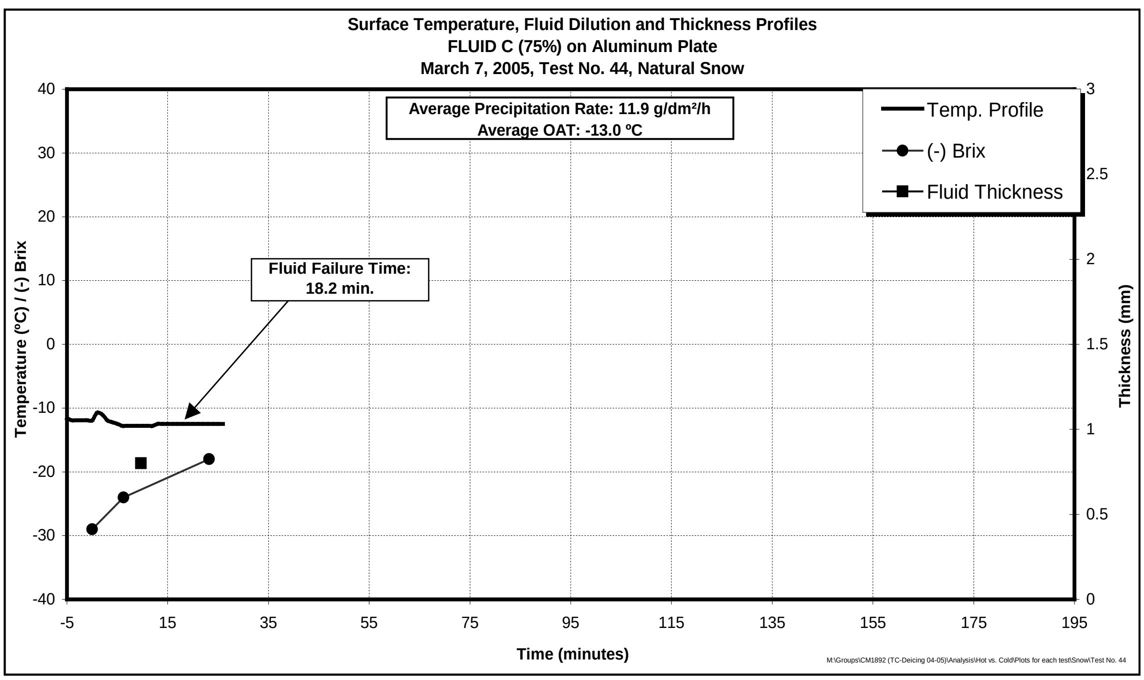

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Box
February 21, 2005, Test No. 34, Natural Snow
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -6.3 ºC
Fluid Failure Time:
15.2 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

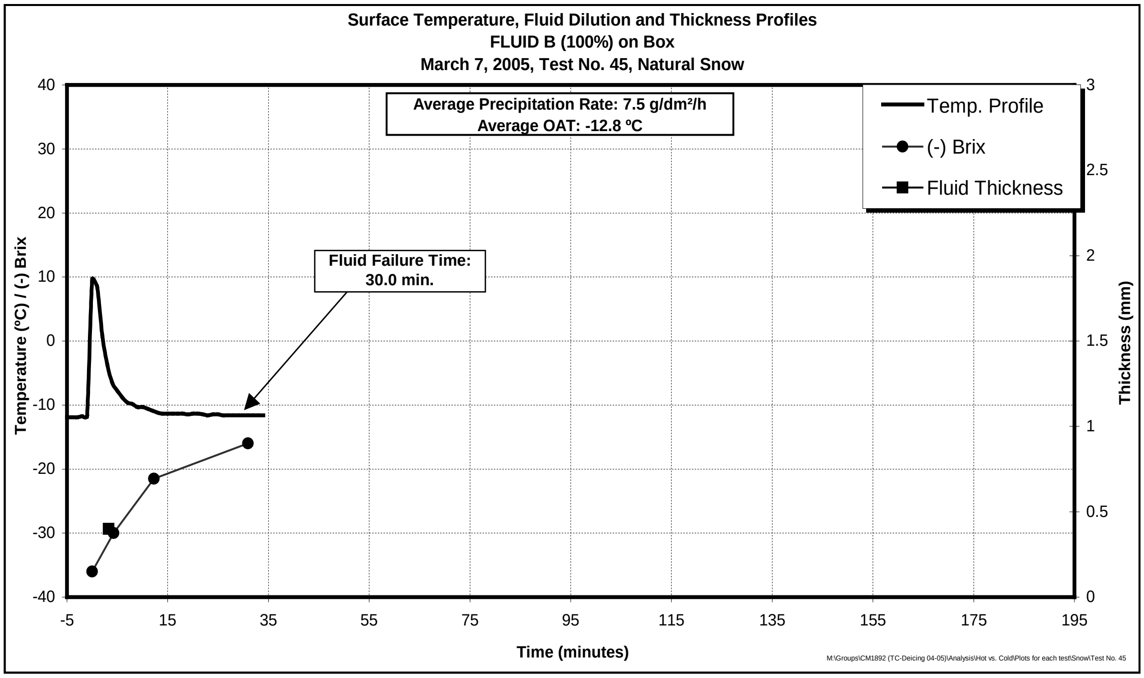

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Aluminum Plate
February 21, 2005, Test No. 36, Natural Snow
Average Precipitation Rate: 14.0 g/dm²/h
Average OAT: -6.2 ºC
Fluid Failure Time:
21.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

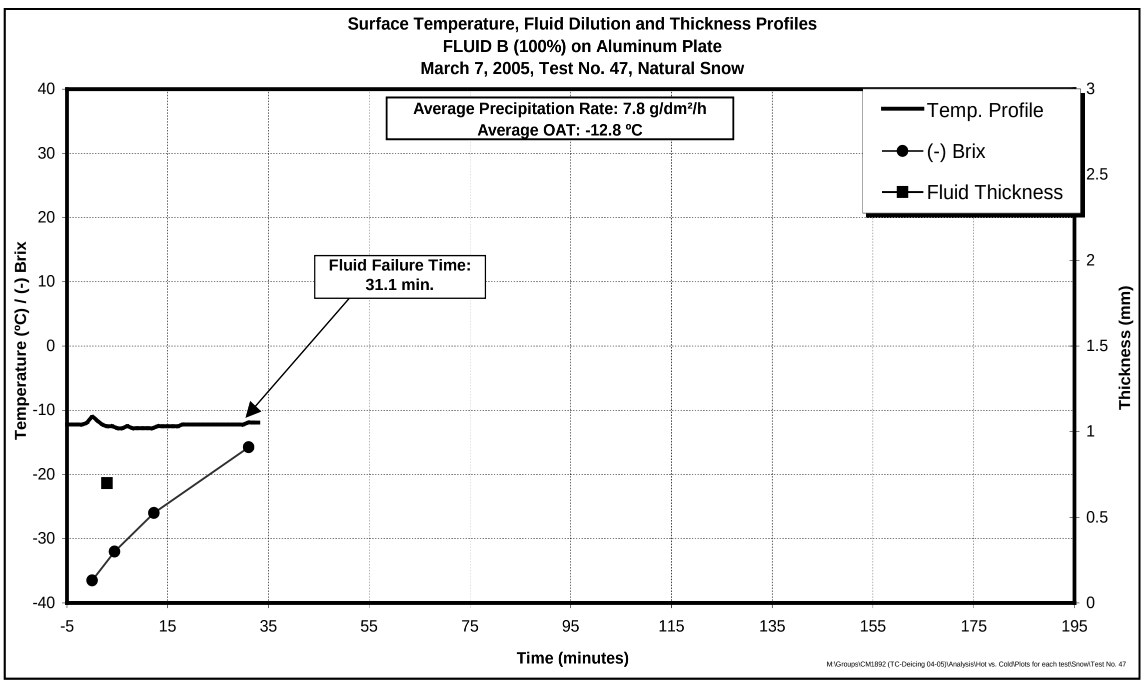

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (Neat) on Box
February 21, 2005, Test No. 37, Natural Snow
Average Precipitation Rate: 13.0 g/dm²/h
Average OAT: -5.9 ºC
Fluid Failure Time:
62.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

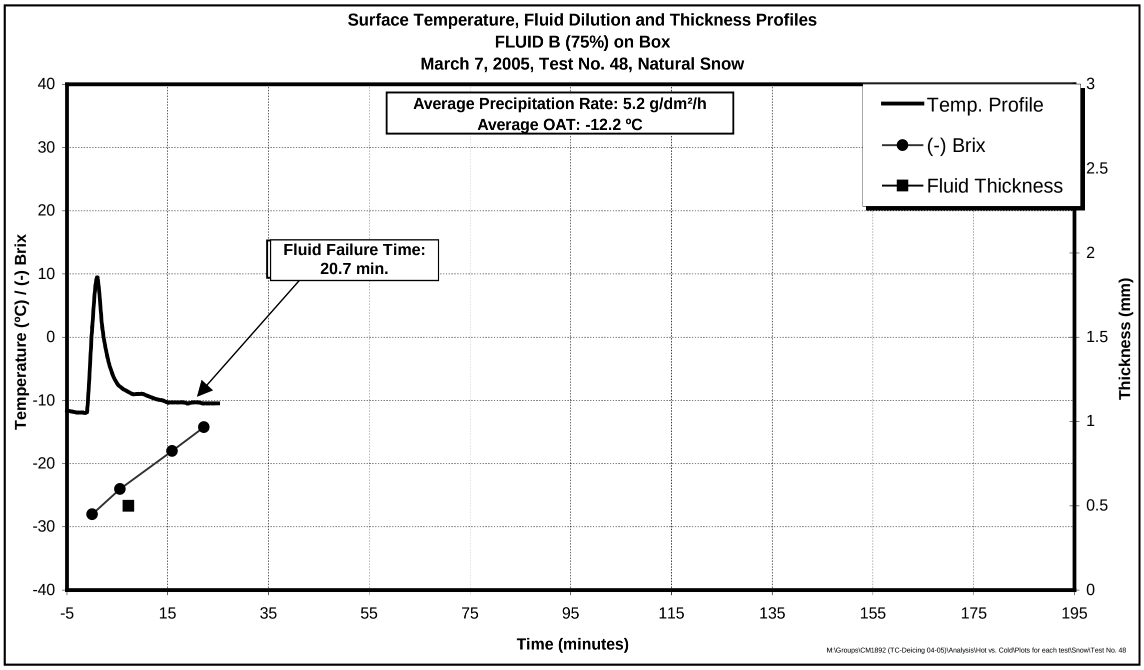

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (Neat) on Aluminum Plate
February 21, 2005, Test No. 39, Natural Snow
Average Precipitation Rate: 12.6 g/dm²/h
Average OAT: -5.9 ºC
Fluid Failure Time:
67.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

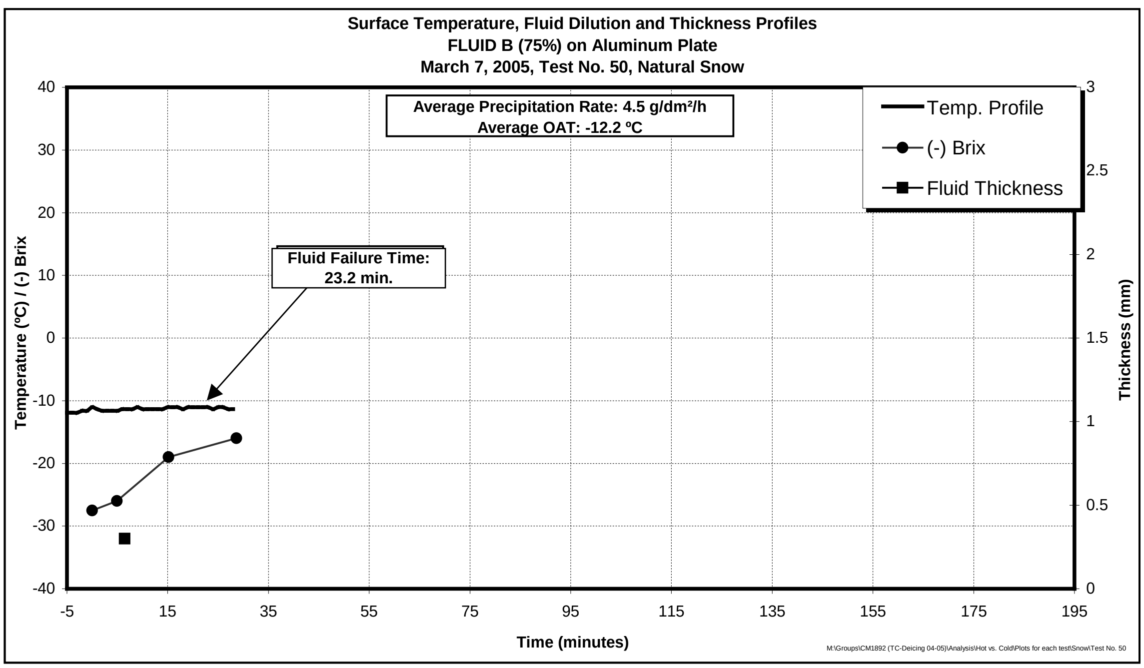

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Box
March 7, 2005, Test No. 42, Natural Snow
Average Precipitation Rate: 11.9 g/dm²/h
Average OAT: -13.0 ºC
Fluid Failure Time: 20.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

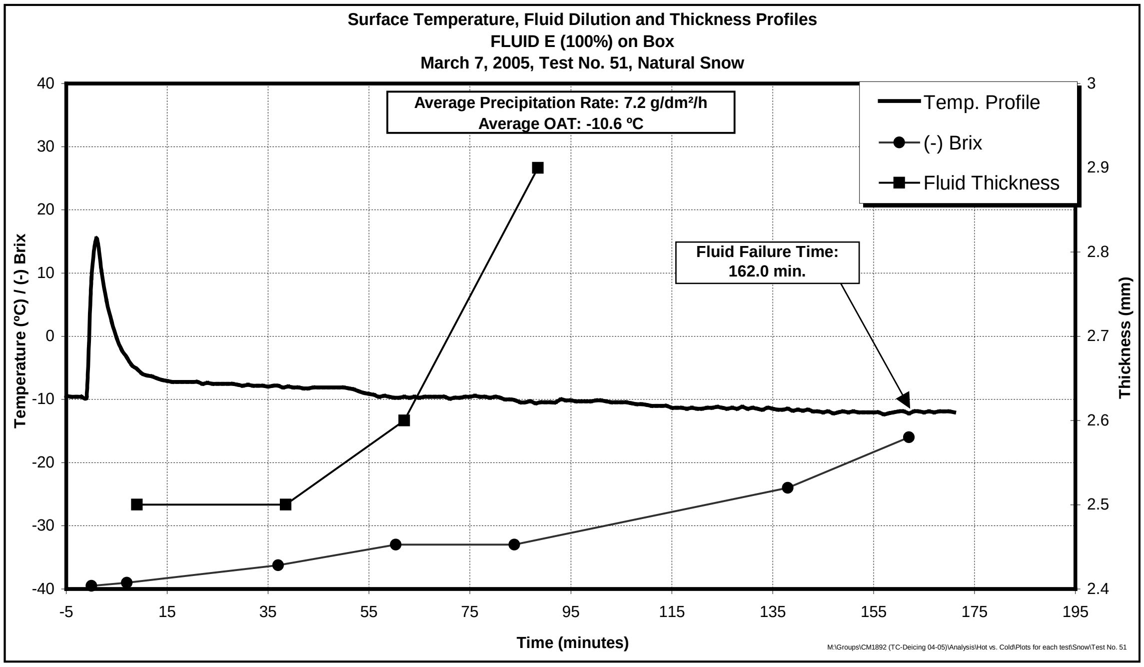

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Aluminum Plate
March 7, 2005, Test No. 44, Natural Snow
Average Precipitation Rate: 11.9 g/dm²/h
Average OAT: -13.0 ºC
Fluid Failure Time: 18.2 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (100%) on Box
March 7, 2005, Test No. 45, Natural Snow
Average Precipitation Rate: 7.5 g/dm²/h
Average OAT: -12.8 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
30.0 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

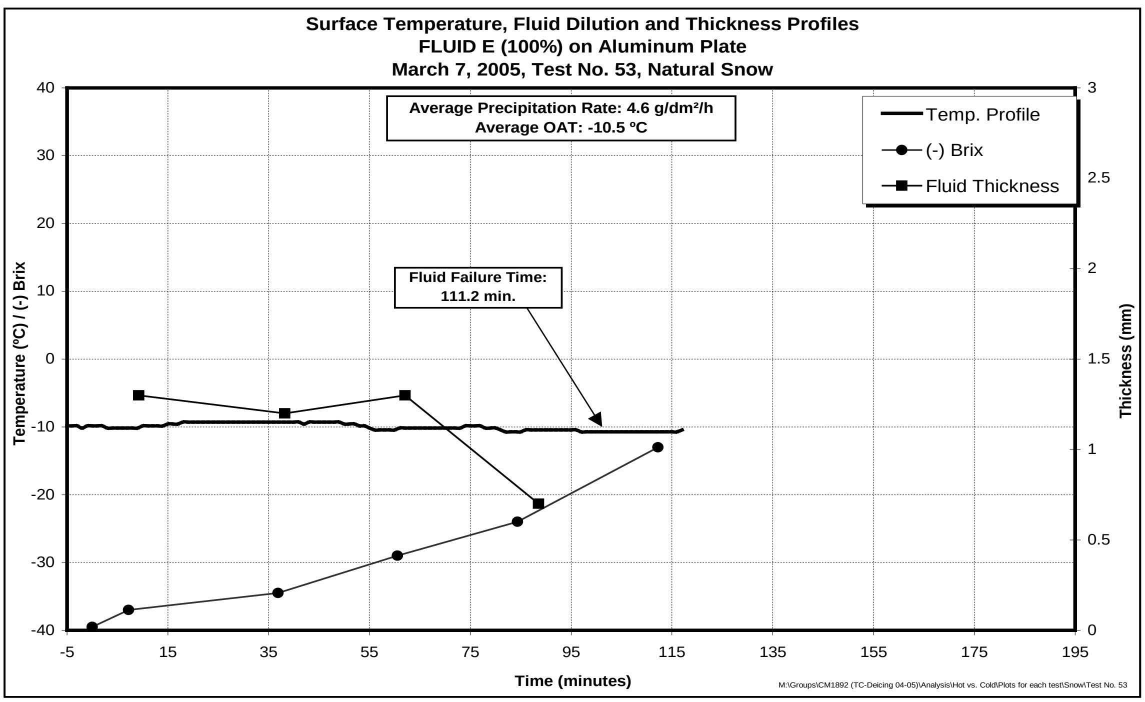

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (100%) on Aluminum Plate
March 7, 2005, Test No. 47, Natural Snow
Average Precipitation Rate: 7.8 g/dm²/h
Average OAT: -12.8 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
31.1 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Box
March 7, 2005, Test No. 48, Natural Snow
Average Precipitation Rate: 5.2 g/dm²/h
Average OAT: -12.2 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
20.7 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

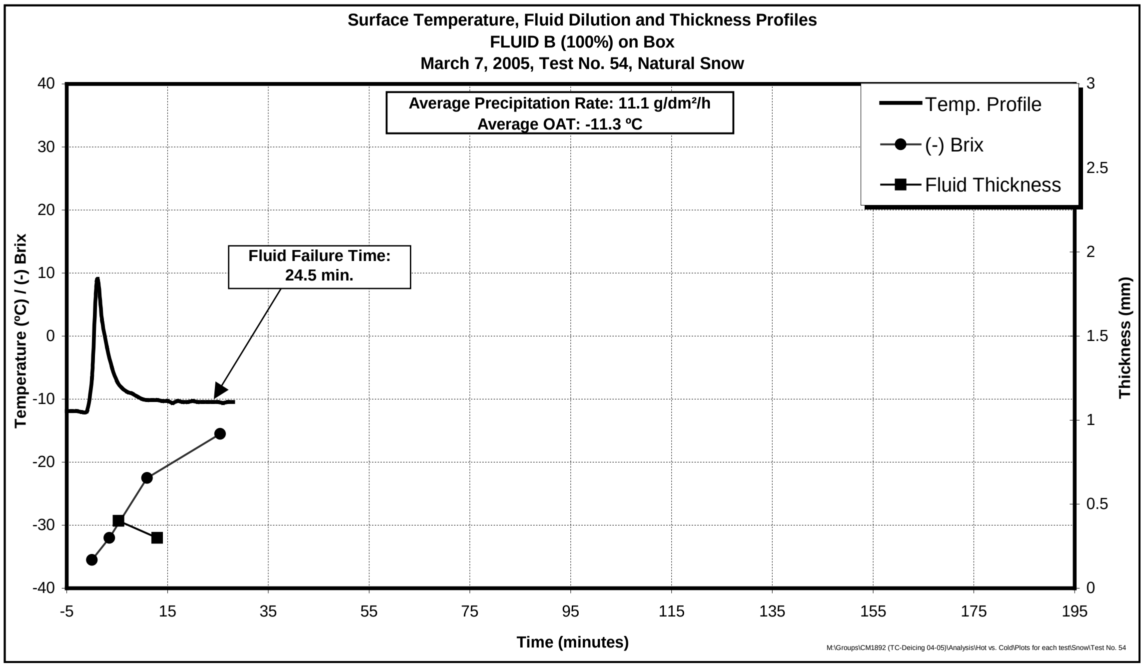

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
March 7, 2005, Test No. 50, Natural Snow
Average Precipitation Rate: 4.5 g/dm²/h
Average OAT: -12.2 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
23.2 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

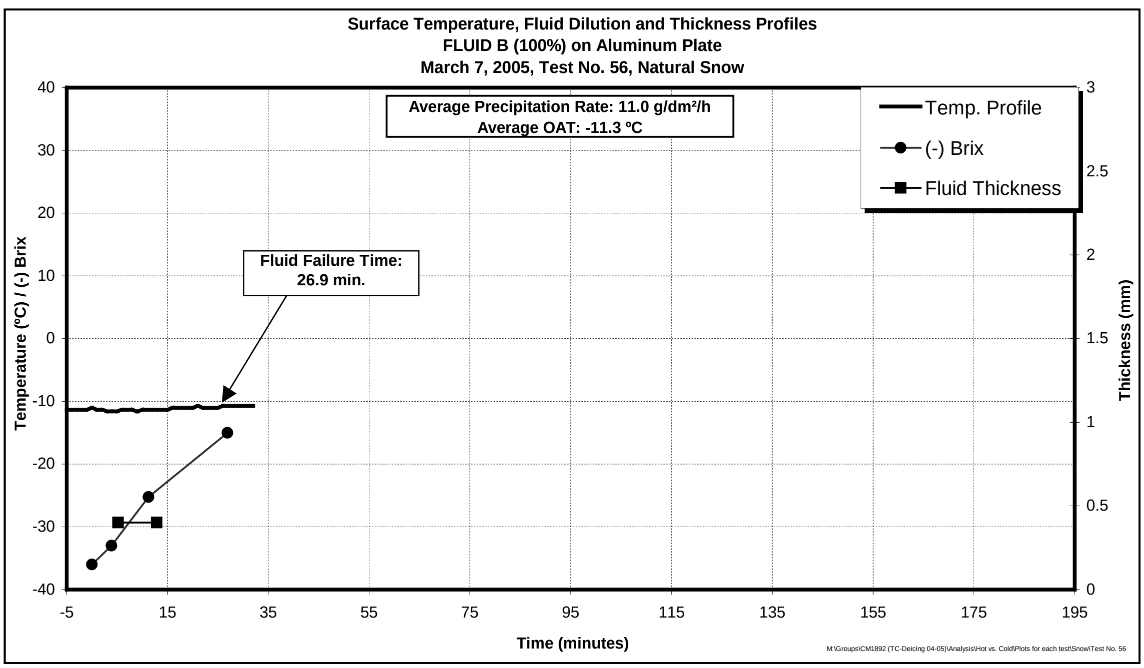


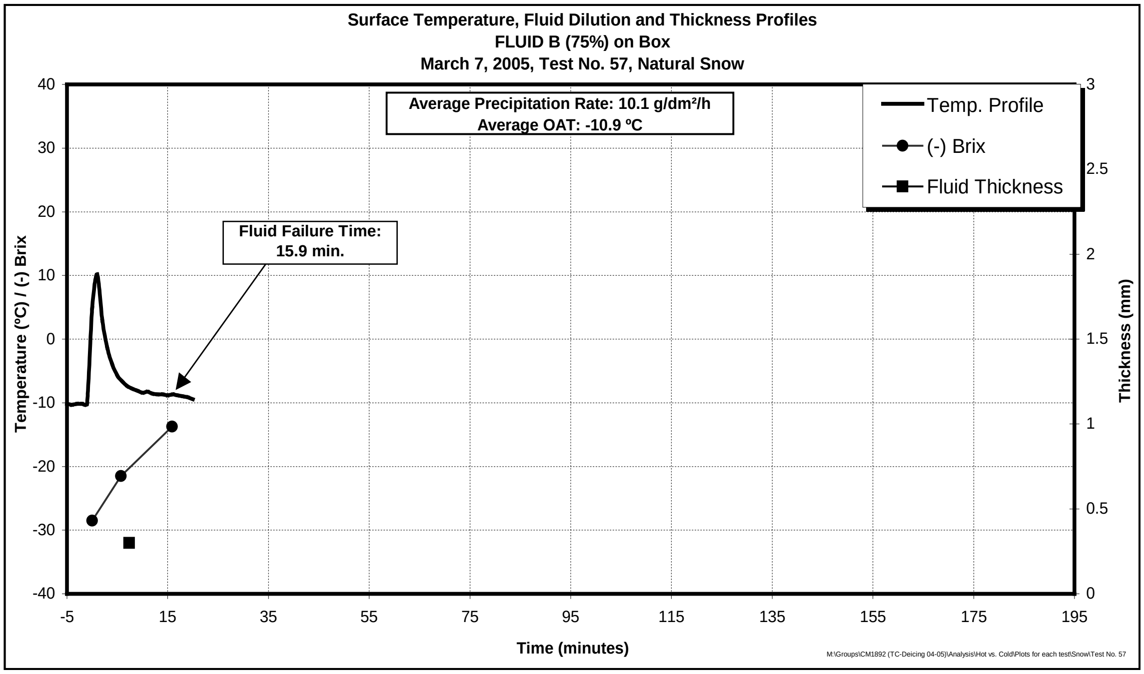
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID E (100%) on Box
March 7, 2005, Test No. 51, Natural Snow
Average Precipitation Rate: 7.2 g/dm²/h
Average OAT: -10.6 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
162.0 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.9
2.8
2.7
2.6
2.5
2.4
-5
15
35
55
75
95
115
135
155
175
195

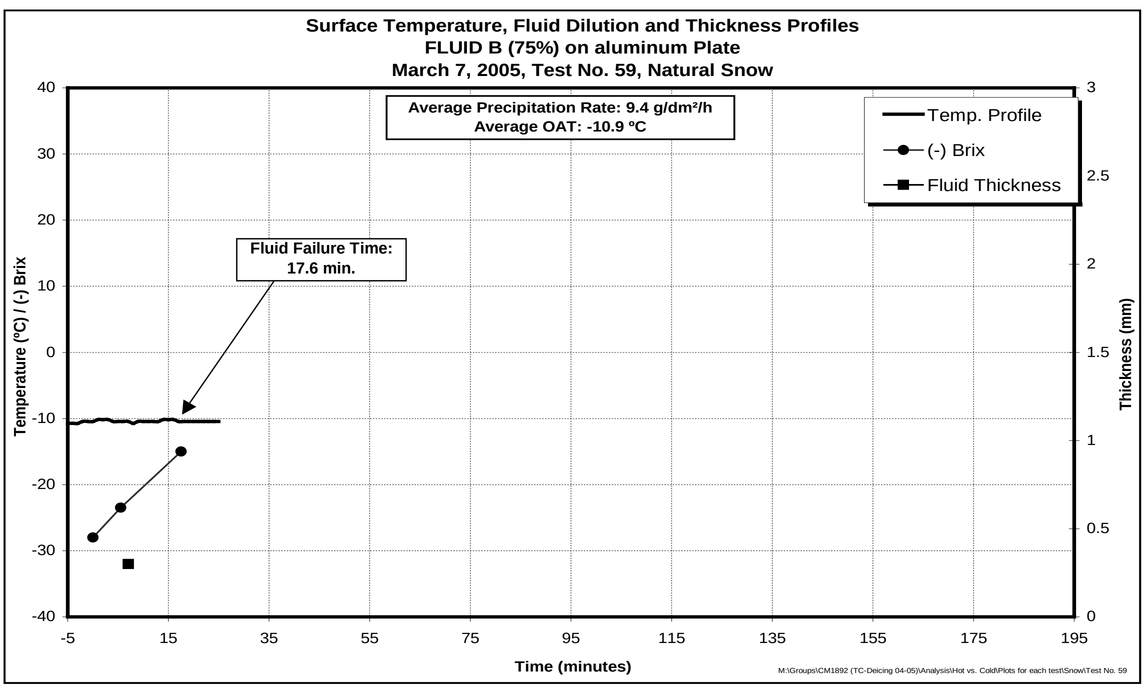


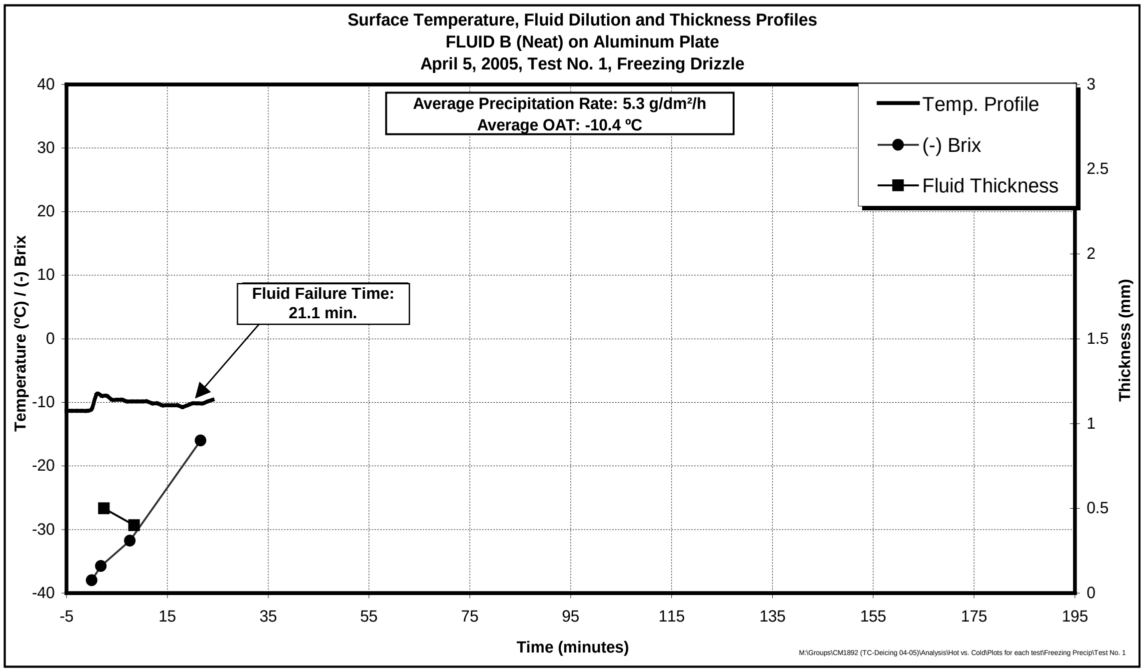
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID E (100%) on Aluminum Plate
March 7, 2005, Test No. 53, Natural Snow
Average Precipitation Rate: 4.6 g/dm²/h
Average OAT: -10.5 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
111.2 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

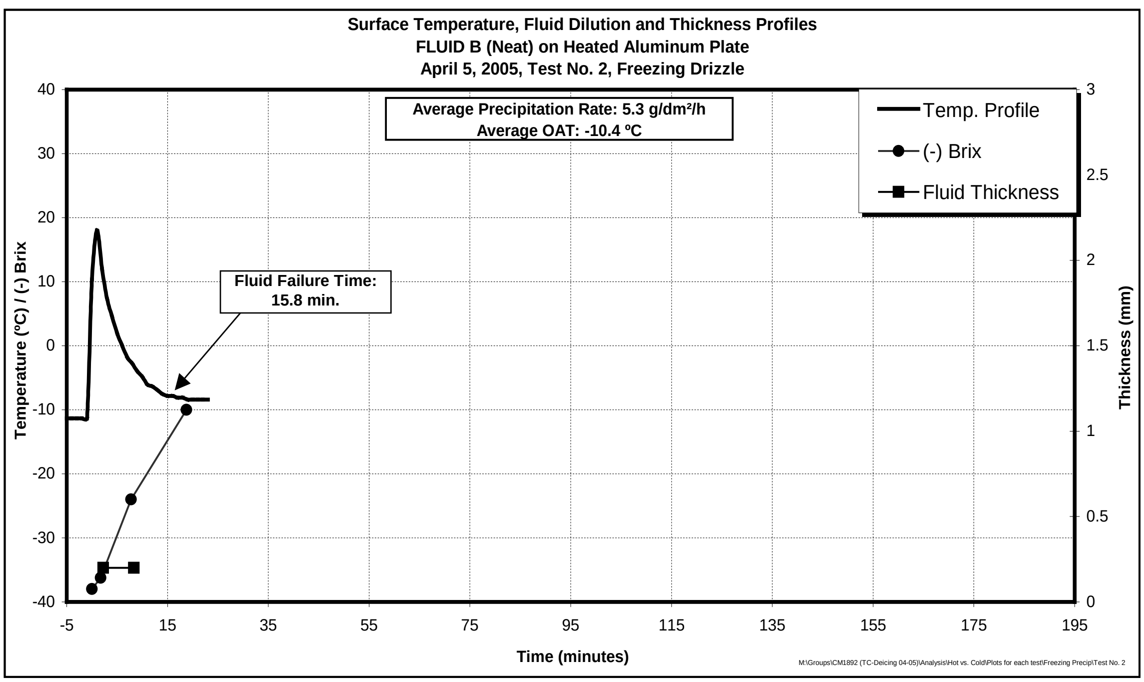

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (100%) on Box
March 7, 2005, Test No. 54, Natural Snow
Average Precipitation Rate: 11.1 g/dm²/h
Average OAT: -11.3 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
24.5 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Snow\Test No. 54

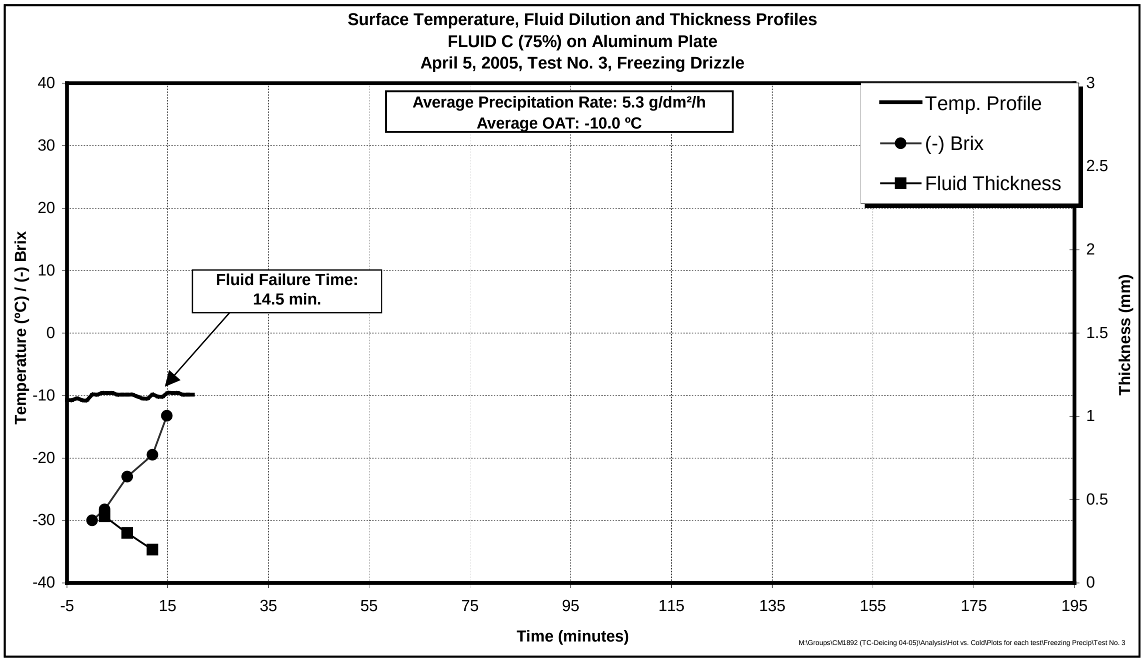

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (100%) on Aluminum Plate
March 7, 2005, Test No. 56, Natural Snow
Average Precipitation Rate: 11.0 g/dm²/h
Average OAT: -11.3 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
26.9 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Snow\Test No. 56

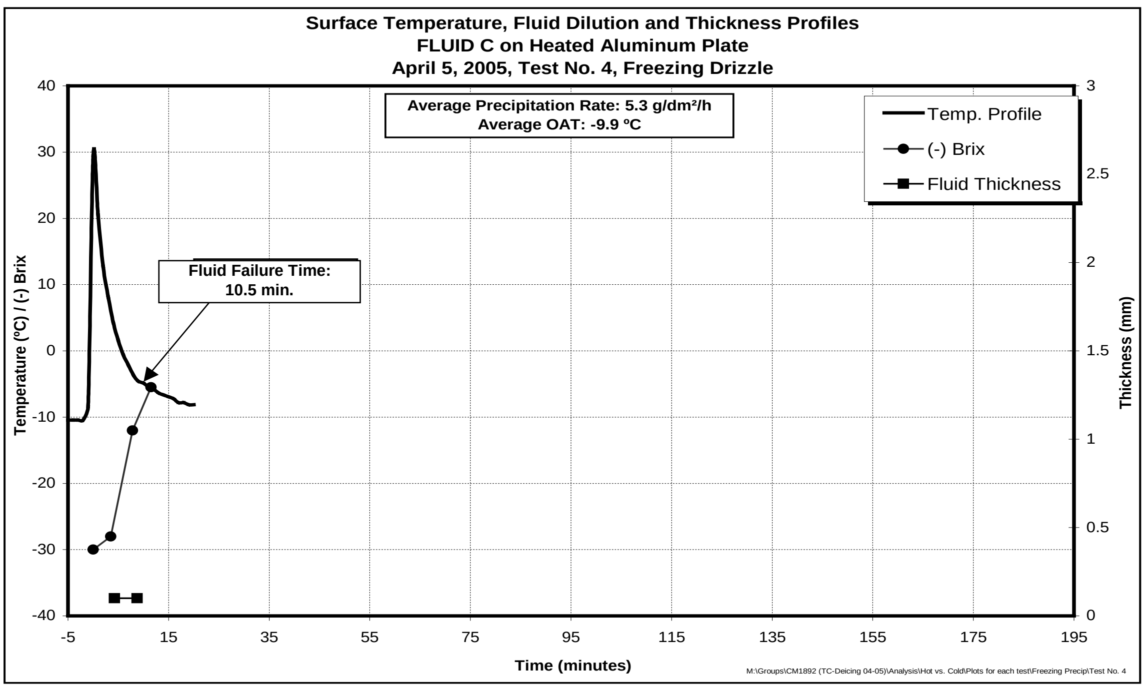

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Box
March 7, 2005, Test No. 57, Natural Snow
Average Precipitation Rate: 10.1 g/dm²/h
Average OAT: -10.9 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
15.9 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Snow\Test No. 57

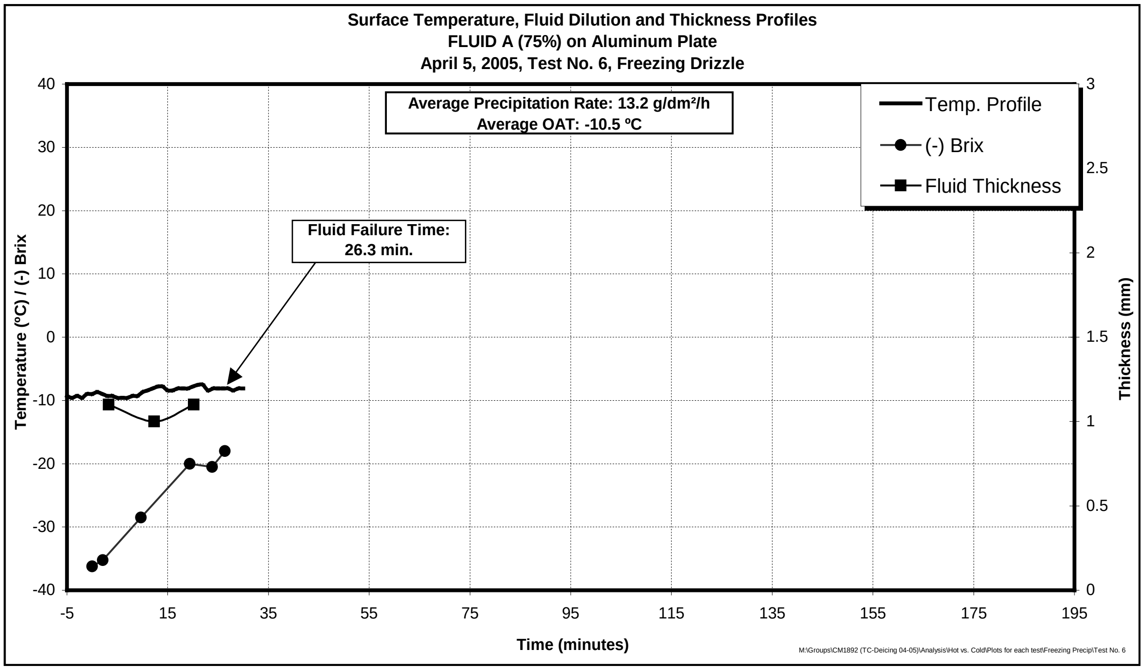

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on aluminum Plate
March 7, 2005, Test No. 59, Natural Snow
Average Precipitation Rate: 9.4 g/dm²/h
Average OAT: -10.9 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
17.6 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Snow\Test No. 59

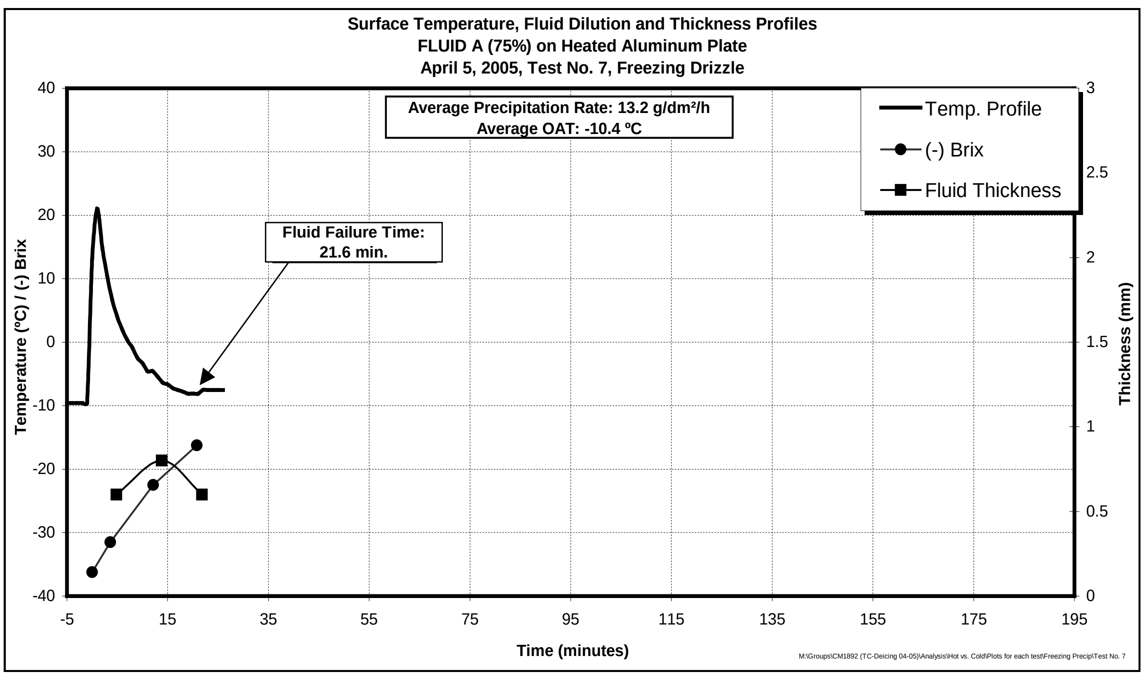

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Aluminum Plate
April 5, 2005, Test No. 1, Freezing Drizzle
Average Precipitation Rate: 5.3 g/dm²/h
Average OAT: -10.4 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
21.1 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 1

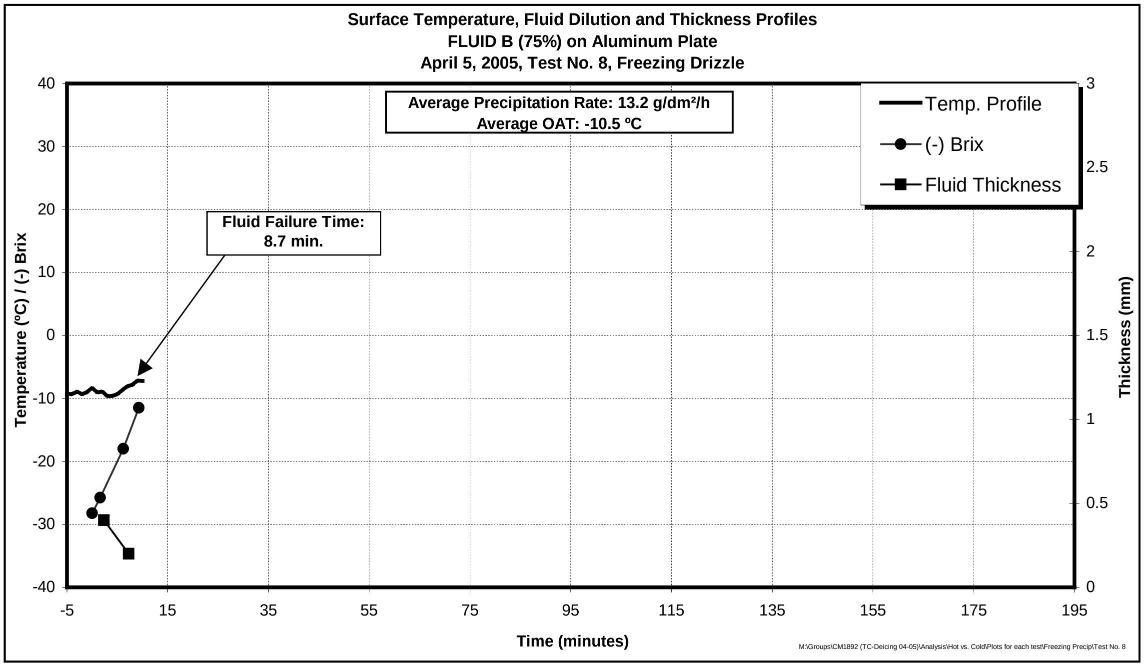

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Heated Aluminum Plate
April 5, 2005, Test No. 2, Freezing Drizzle
Average Precipitation Rate: 5.3 g/dm²/h
Average OAT: -10.4 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
15.8 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 2

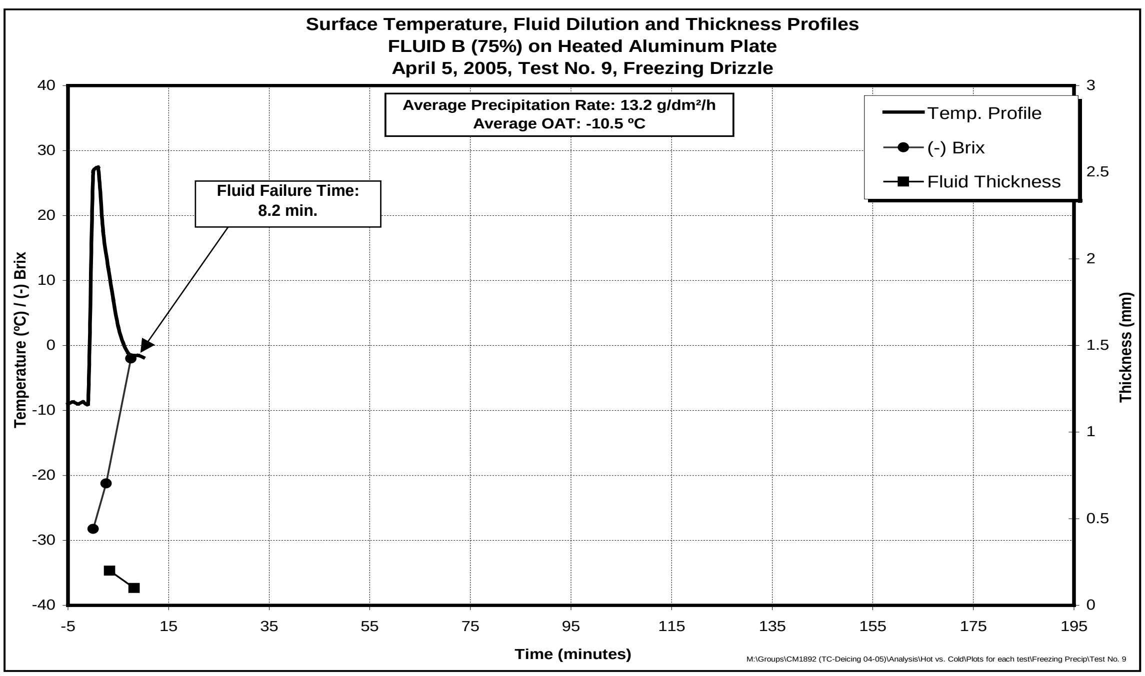

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Aluminum Plate
April 5, 2005, Test No. 3, Freezing Drizzle
Average Precipitation Rate: 5.3 g/dm²/h
Average OAT: -10.0 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
14.5 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

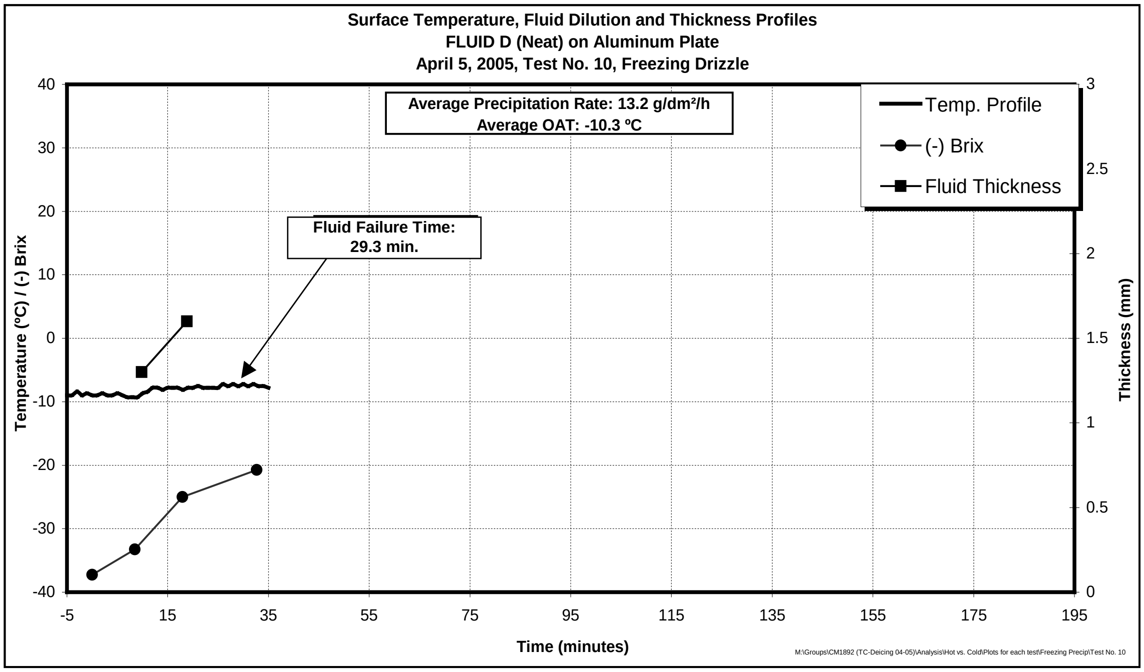

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C on Heated Aluminum Plate
April 5, 2005, Test No. 4, Freezing Drizzle
Average Precipitation Rate: 5.3 g/dm²/h
Average OAT: -9.9 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
10.5 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

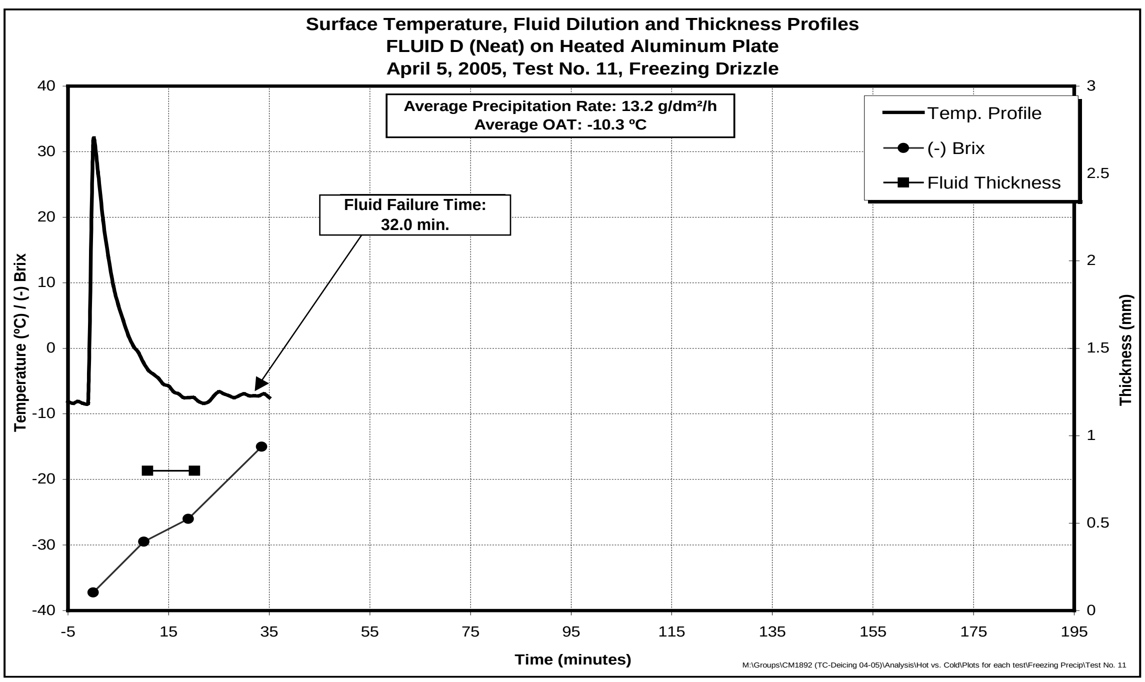

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Aluminum Plate
April 5, 2005, Test No. 6, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.5 ºC
Fluid Failure Time:
26.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 6

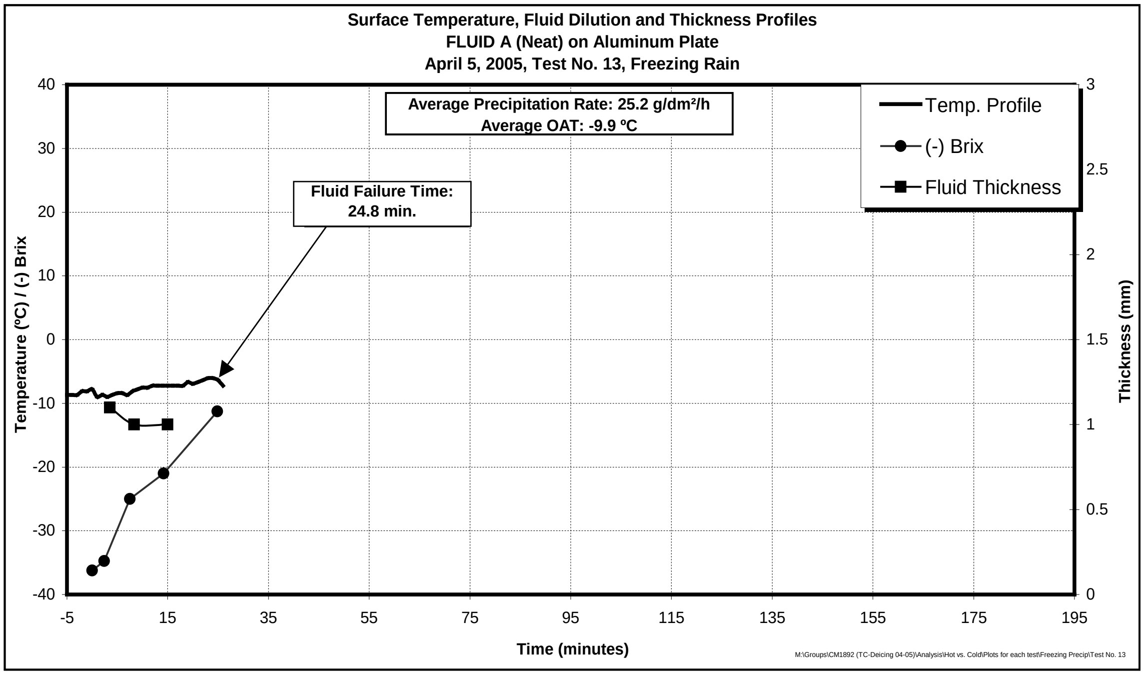

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Heated Aluminum Plate
April 5, 2005, Test No. 7, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.4 ºC
Fluid Failure Time:
21.6 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 7

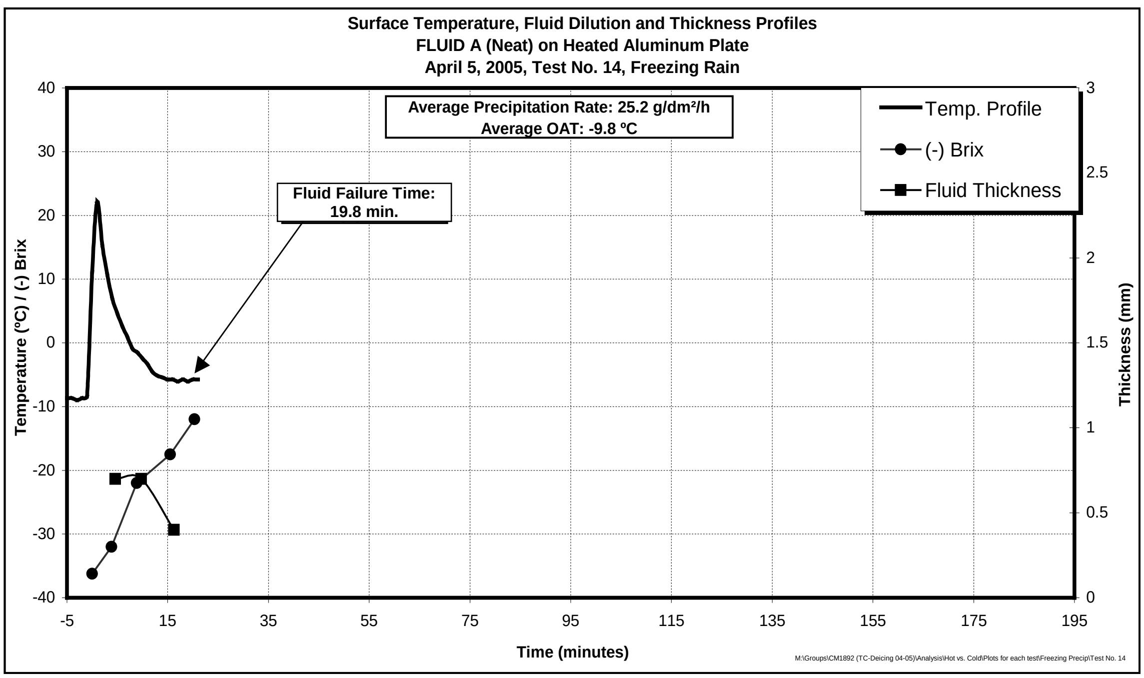

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
April 5, 2005, Test No. 8, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.5 ºC
Fluid Failure Time:
8.7 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

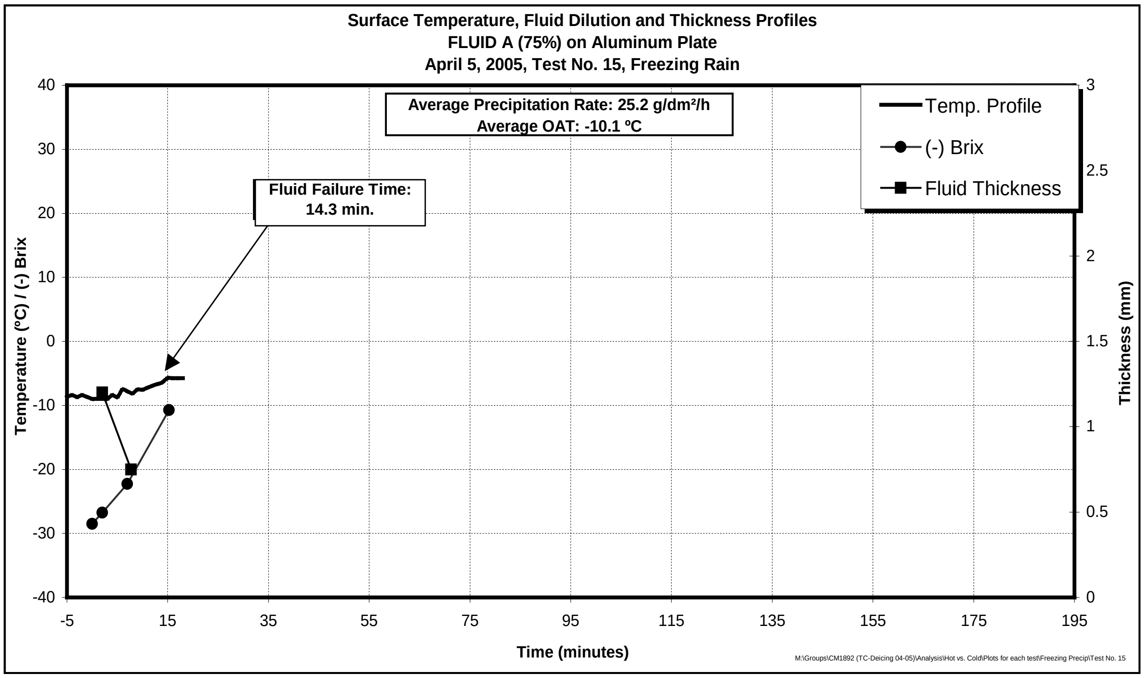

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Heated Aluminum Plate
April 5, 2005, Test No. 9, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.5 ºC
Fluid Failure Time:
8.2 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

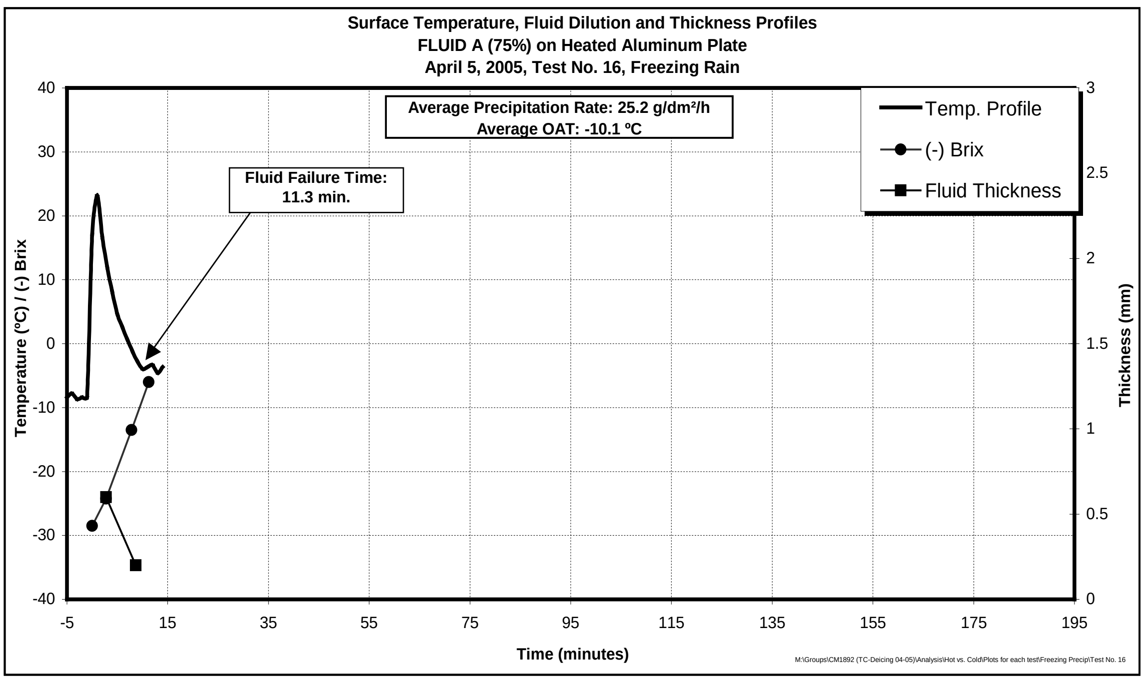

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (Neat) on Aluminum Plate
April 5, 2005, Test No. 10, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.3 ºC
Fluid Failure Time:
29.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

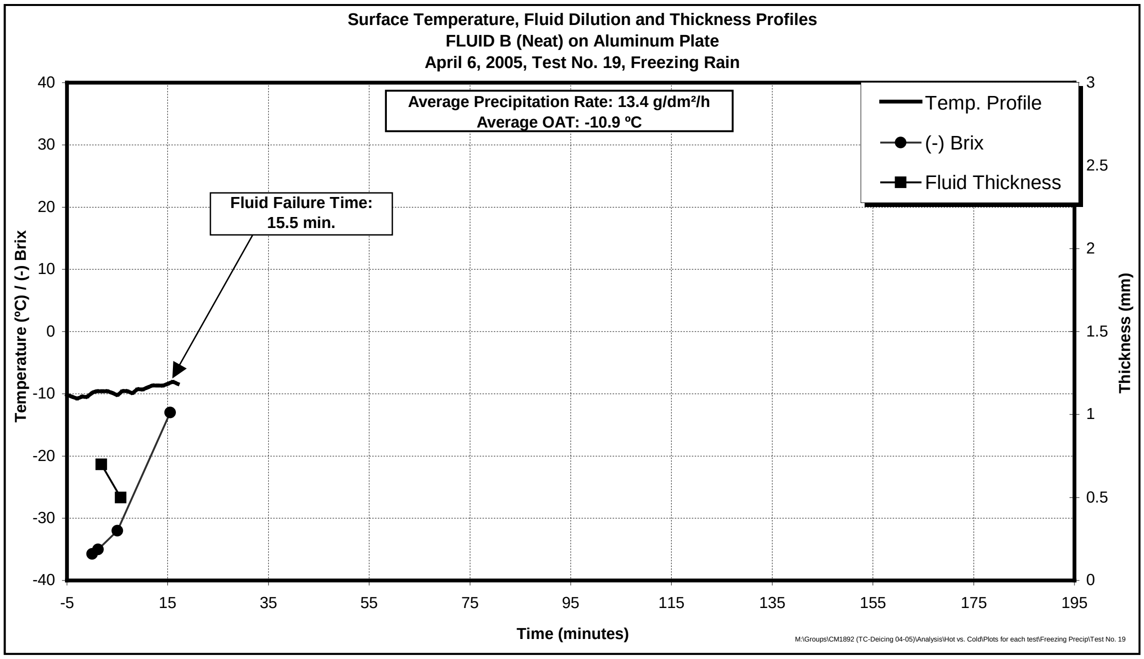

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (Neat) on Heated Aluminum Plate
April 5, 2005, Test No. 11, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.3 ºC
Fluid Failure Time:
32.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

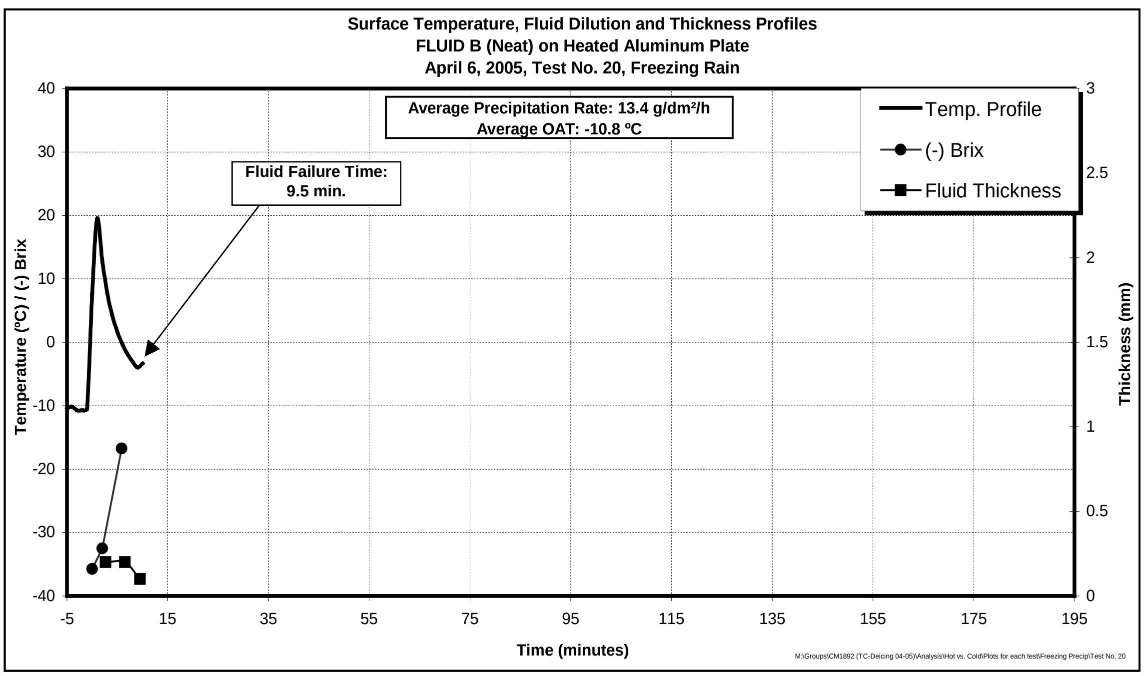

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (Neat) on Aluminum Plate
April 5, 2005, Test No. 13, Freezing Rain
Average Precipitation Rate: 25.2 g/dm²/h
Average OAT: -9.9 ºC
Fluid Failure Time:
24.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

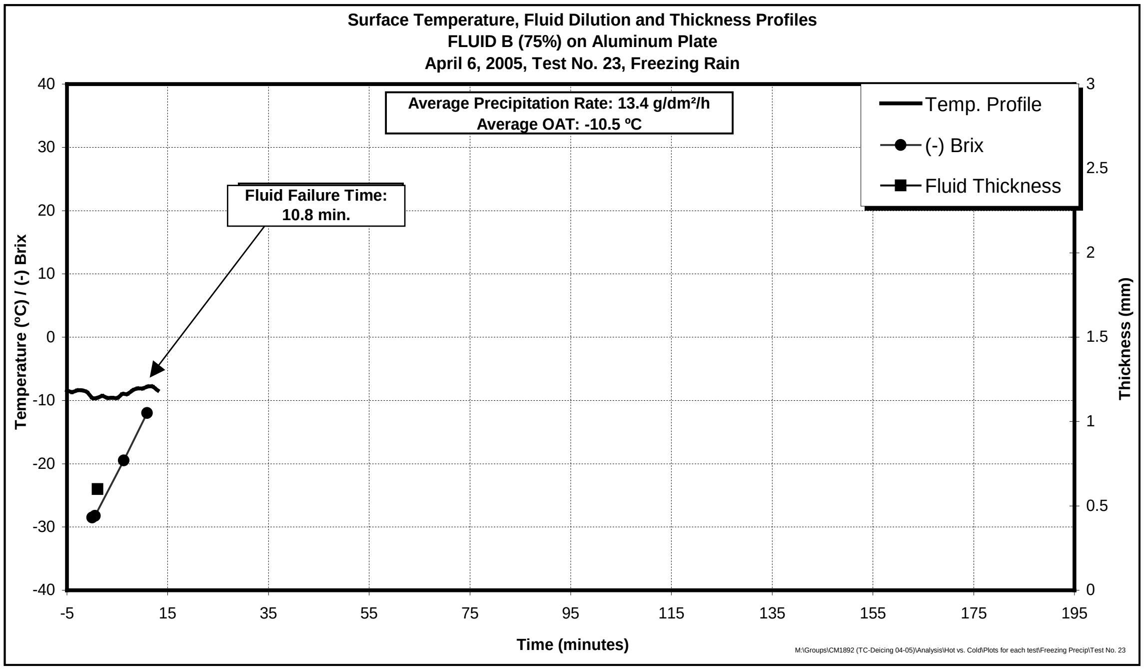

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (Neat) on Heated Aluminum Plate
April 5, 2005, Test No. 14, Freezing Rain
Average Precipitation Rate: 25.2 g/dm²/h
Average OAT: -9.8 ºC
Fluid Failure Time:
19.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

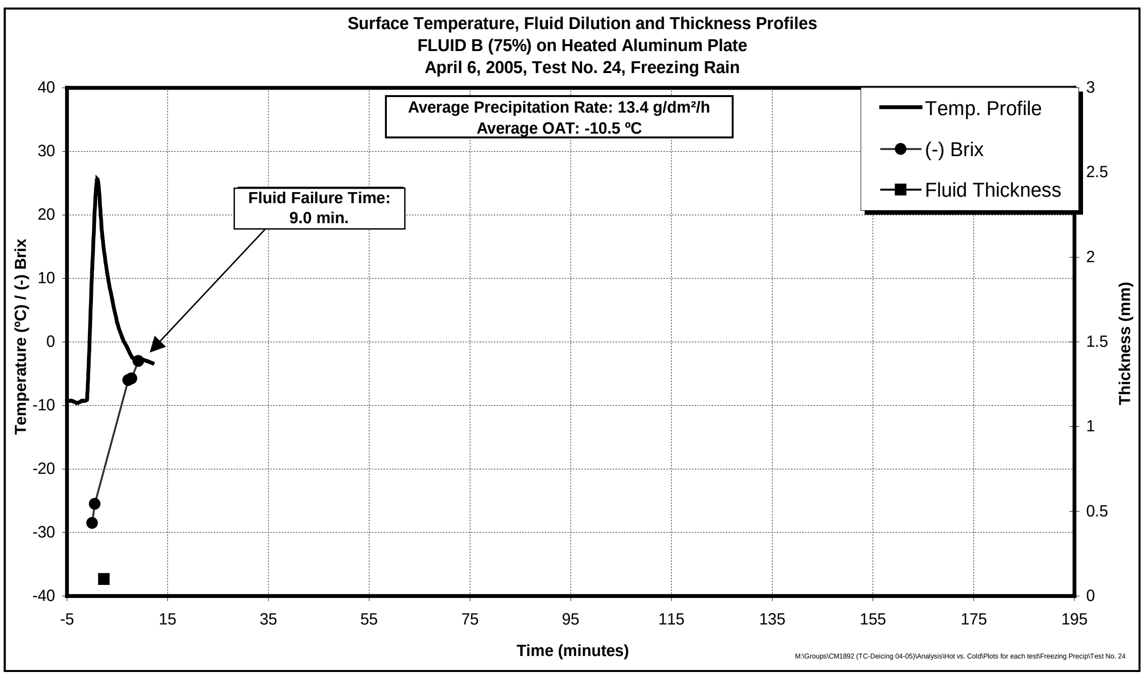

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Aluminum Plate
April 5, 2005, Test No. 15, Freezing Rain
Average Precipitation Rate: 25.2 g/dm²/h
Average OAT: -10.1 ºC
Fluid Failure Time:
14.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

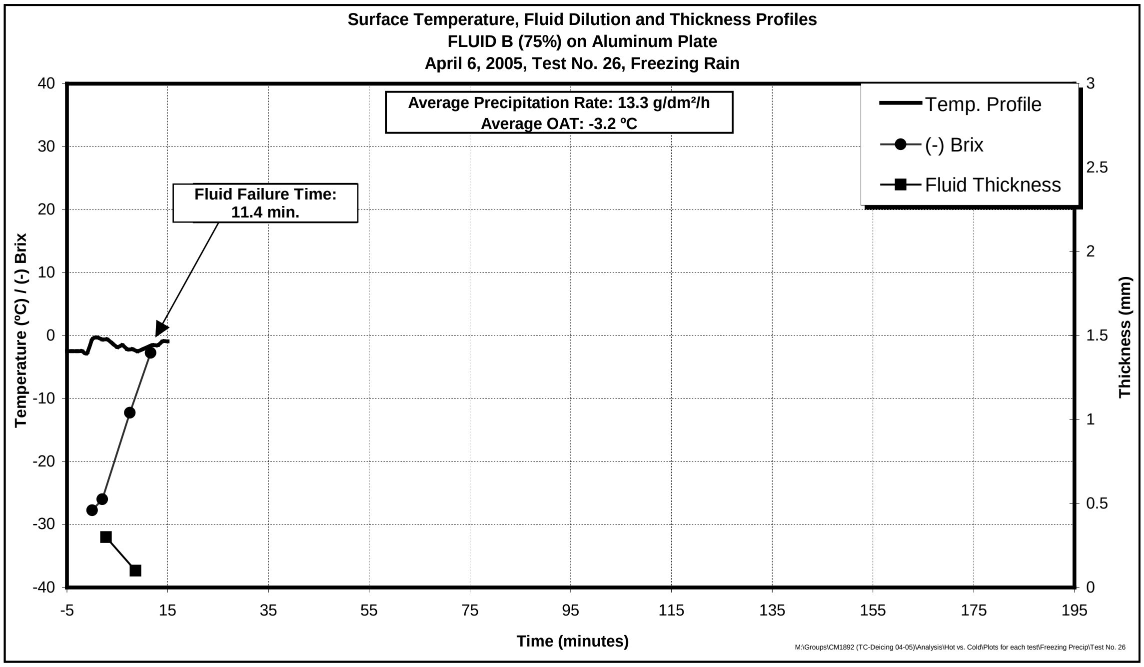

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Heated Aluminum Plate
April 5, 2005, Test No. 16, Freezing Rain
Average Precipitation Rate: 25.2 g/dm²/h
Average OAT: -10.1 ºC
Fluid Failure Time:
11.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

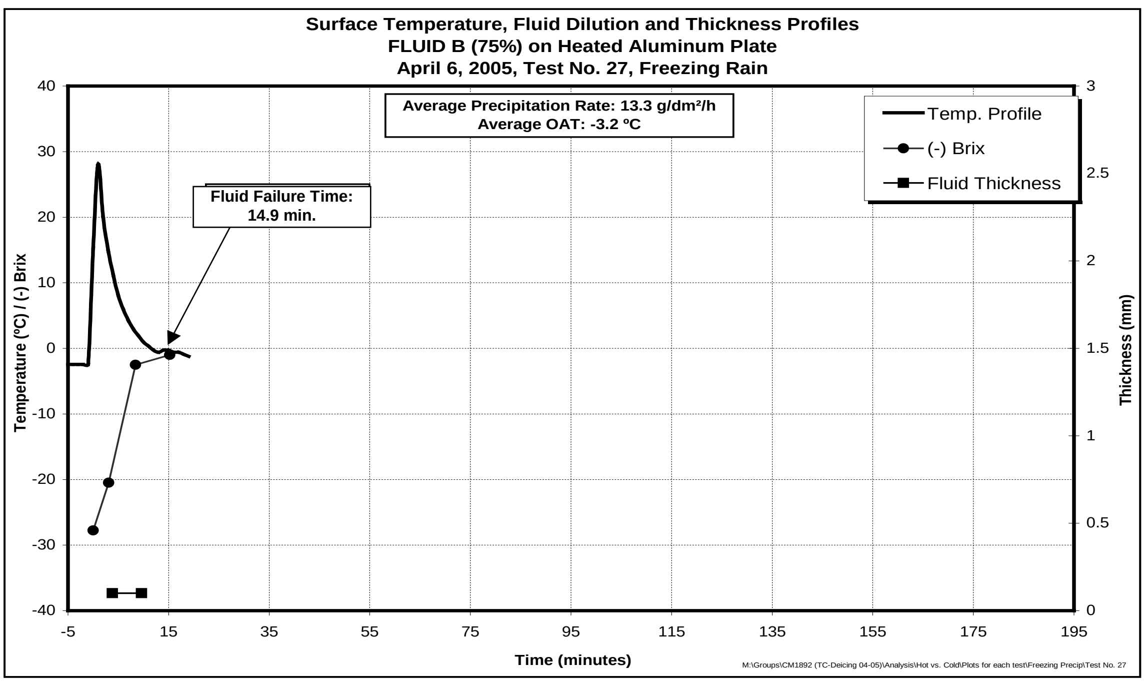

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Aluminum Plate
April 6, 2005, Test No. 19, Freezing Rain
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -10.9 ºC
Fluid Failure Time:
15.5 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 19

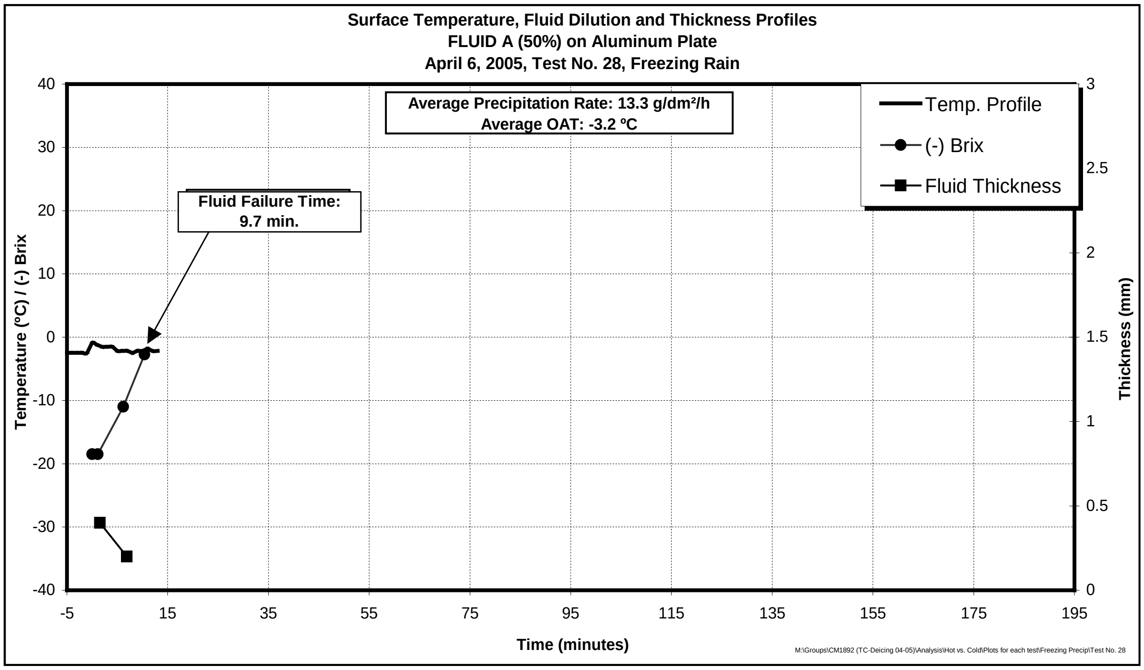

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Heated Aluminum Plate
April 6, 2005, Test No. 20, Freezing Rain
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -10.8 ºC
Fluid Failure Time:
9.5 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 20


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
April 6, 2005, Test No. 23, Freezing Rain
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -10.5 ºC
Fluid Failure Time:
10.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

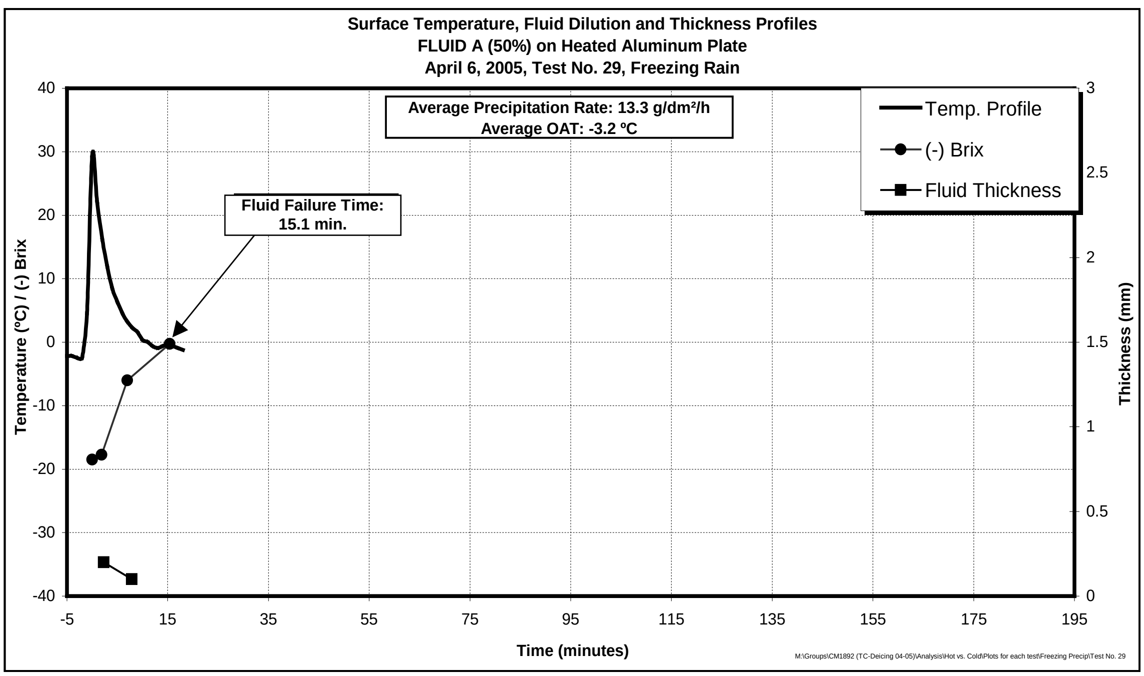

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Heated Aluminum Plate
April 6, 2005, Test No. 24, Freezing Rain
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -10.5 ºC
Fluid Failure Time:
9.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
April 6, 2005, Test No. 26, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.2 ºC
Fluid Failure Time:
11.4 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 26

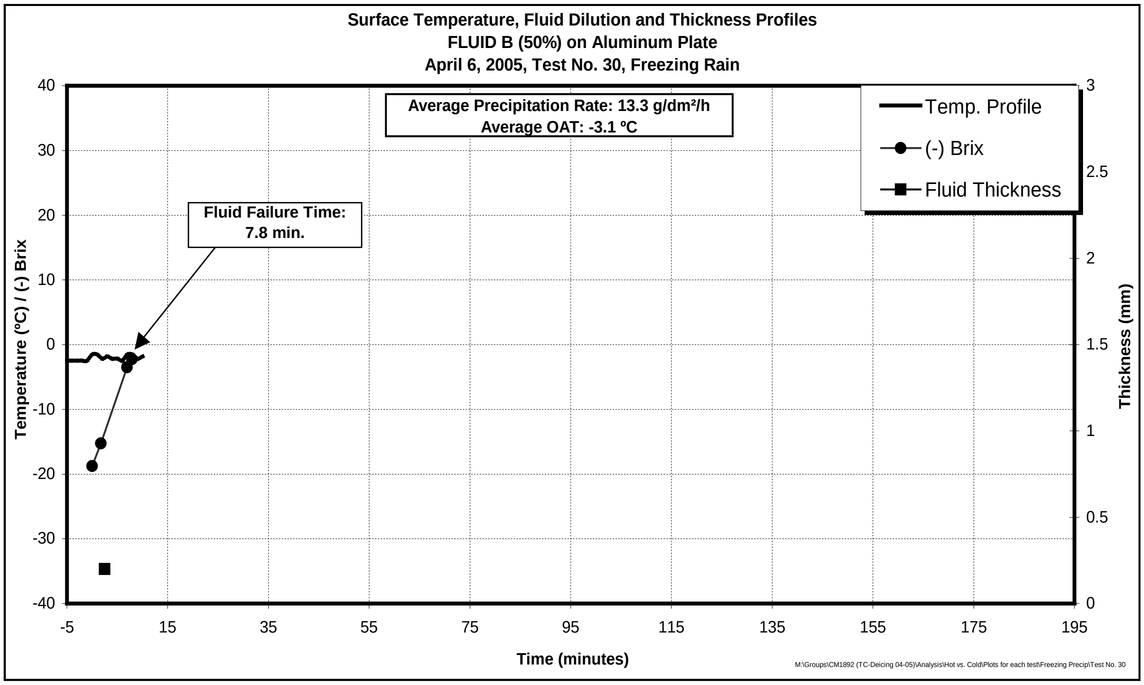

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Heated Aluminum Plate
April 6, 2005, Test No. 27, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.2 ºC
Fluid Failure Time:
14.9 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 27

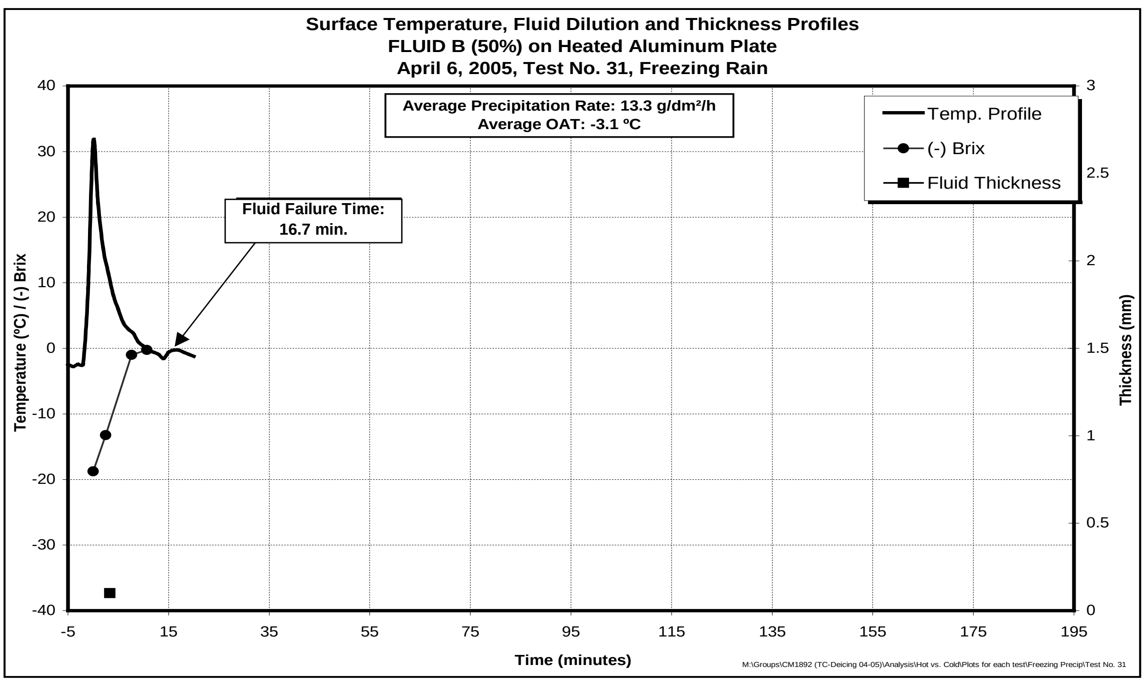


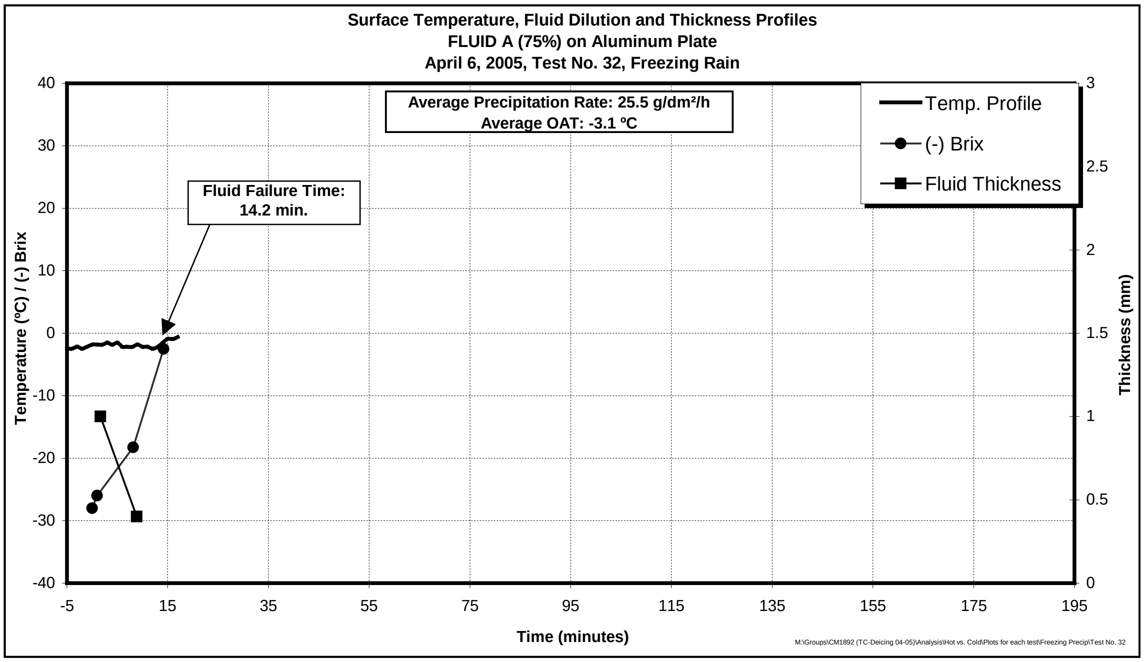
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Aluminum Plate
April 6, 2005, Test No. 28, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.2 ºC
Fluid Failure Time:
9.7 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

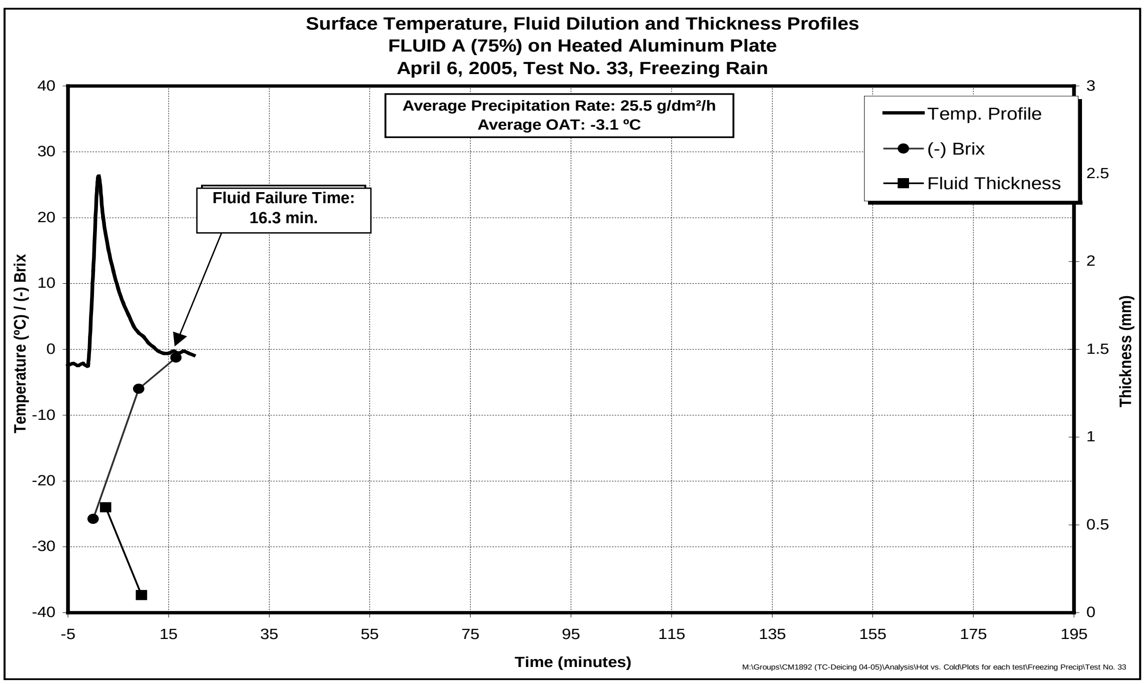


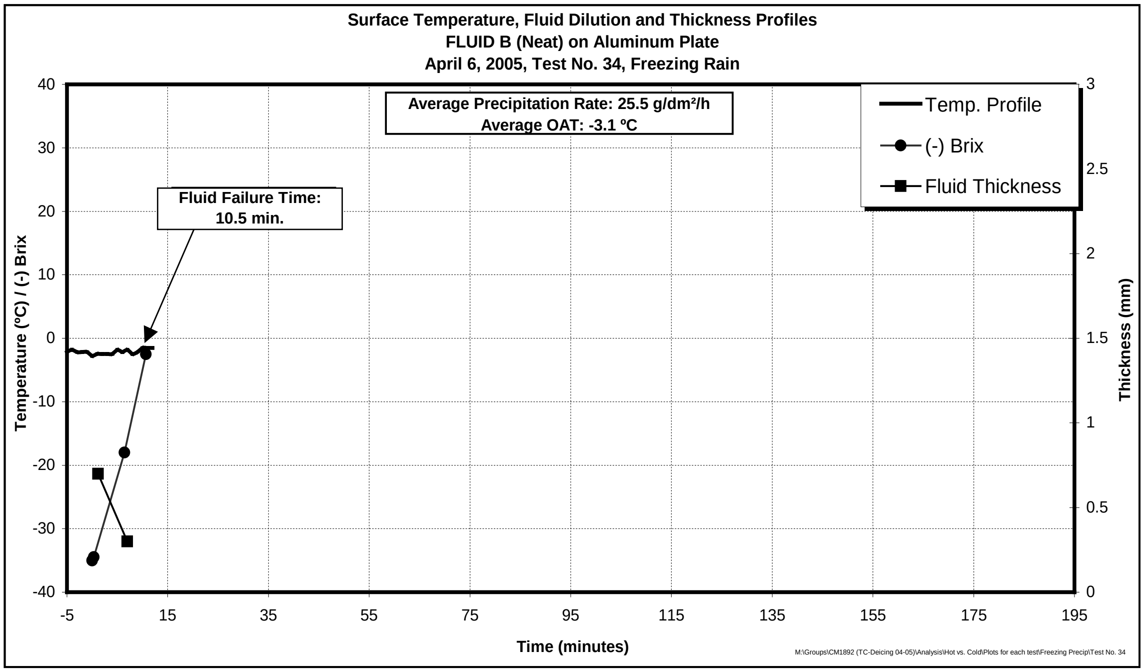
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Heated Aluminum Plate
April 6, 2005, Test No. 29, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.2 ºC
Fluid Failure Time:
15.1 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

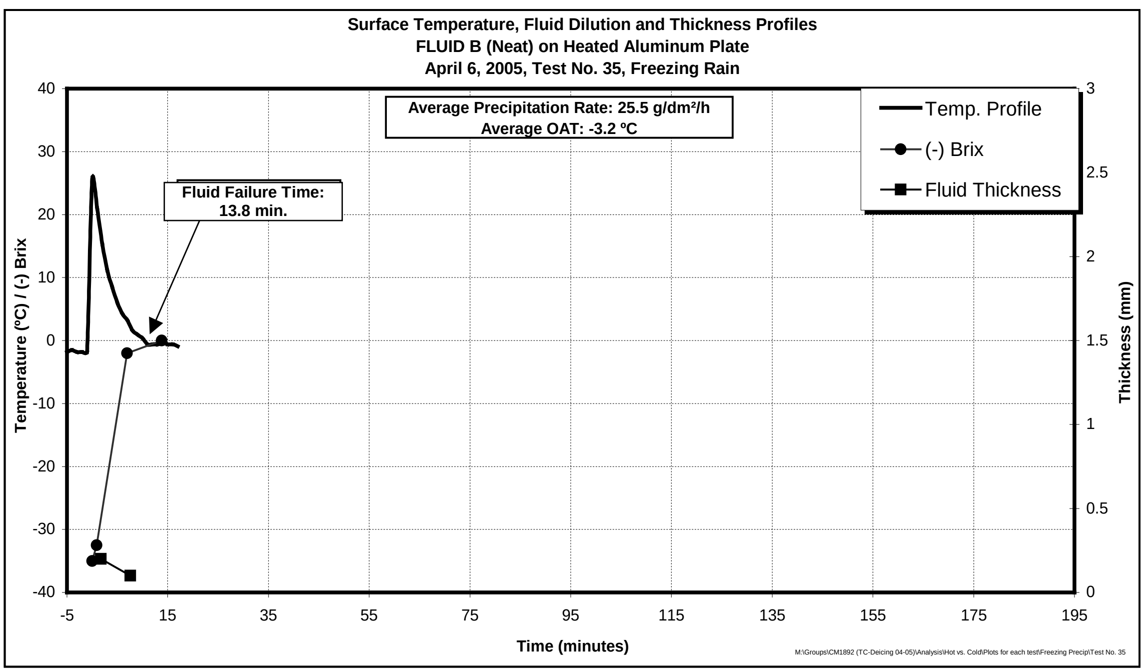

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (50%) on Aluminum Plate
April 6, 2005, Test No. 30, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
7.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 30

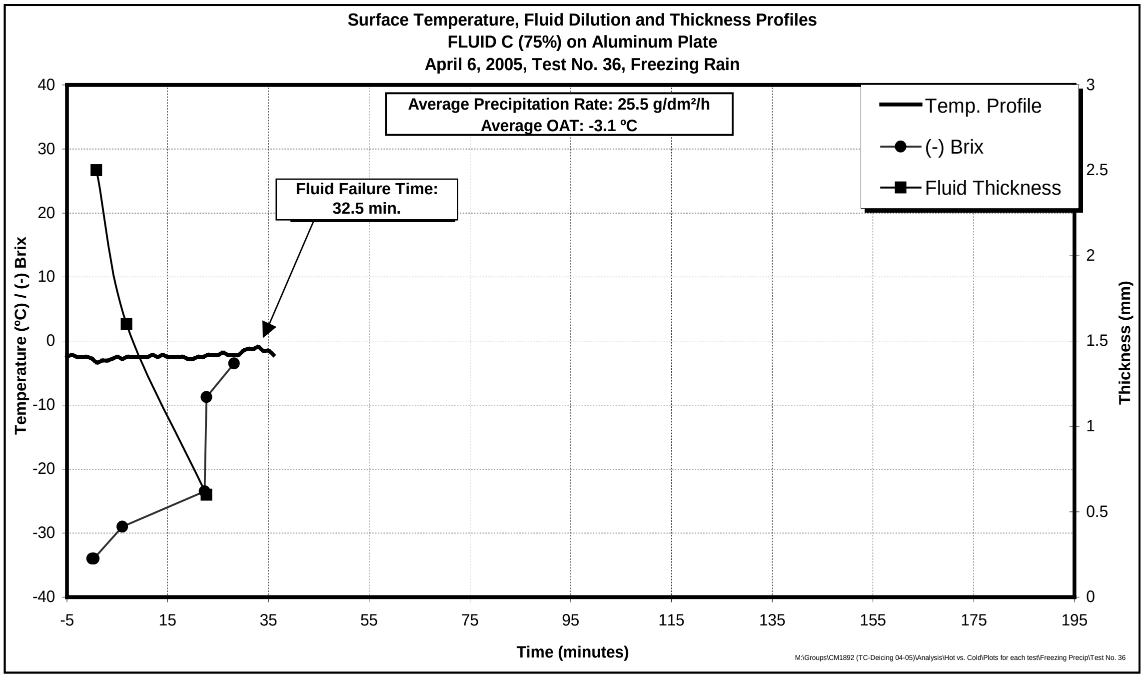

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (50%) on Heated Aluminum Plate
April 6, 2005, Test No. 31, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
16.7 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 31

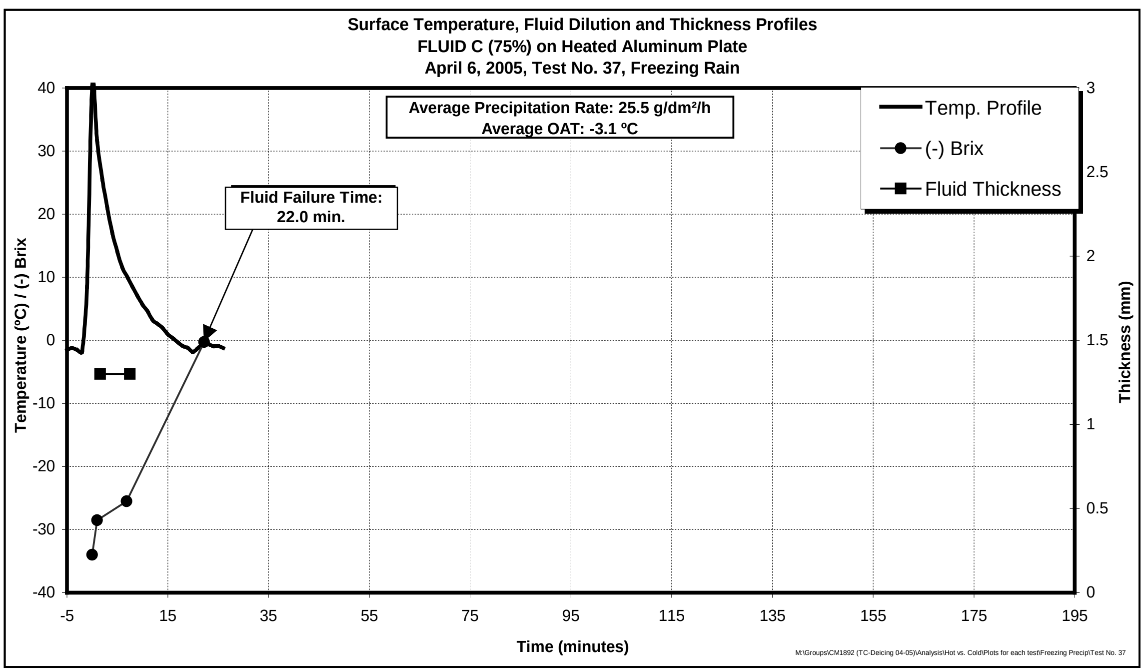

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Aluminum Plate
April 6, 2005, Test No. 32, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
14.2 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 32

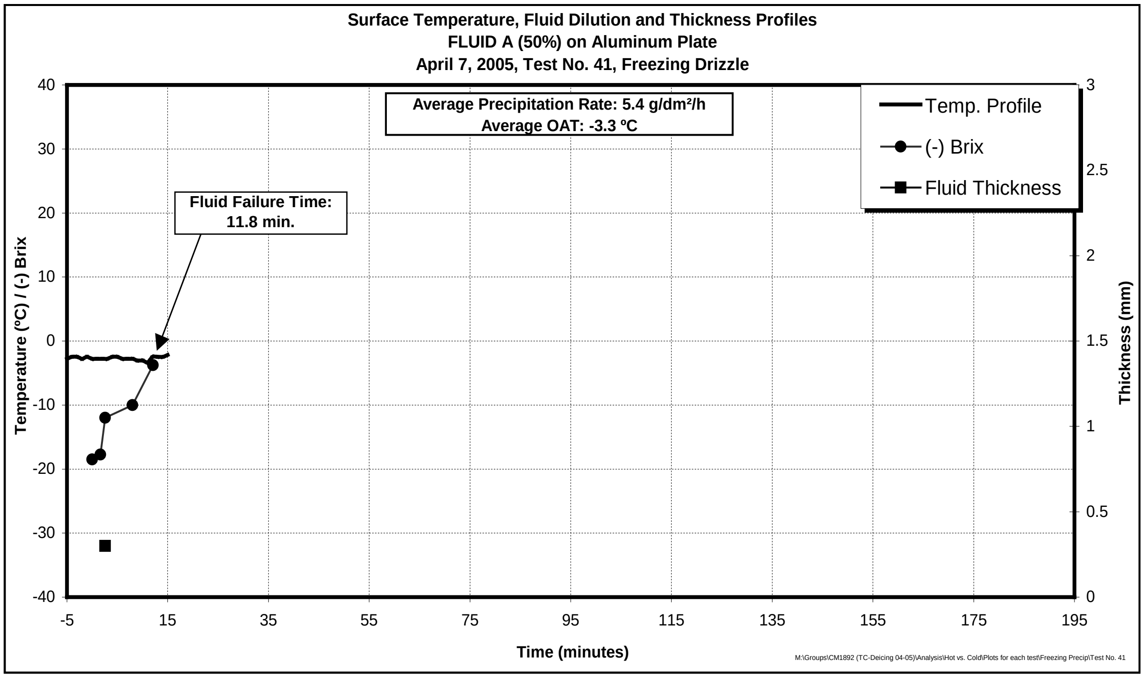

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Heated Aluminum Plate
April 6, 2005, Test No. 33, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
16.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 33

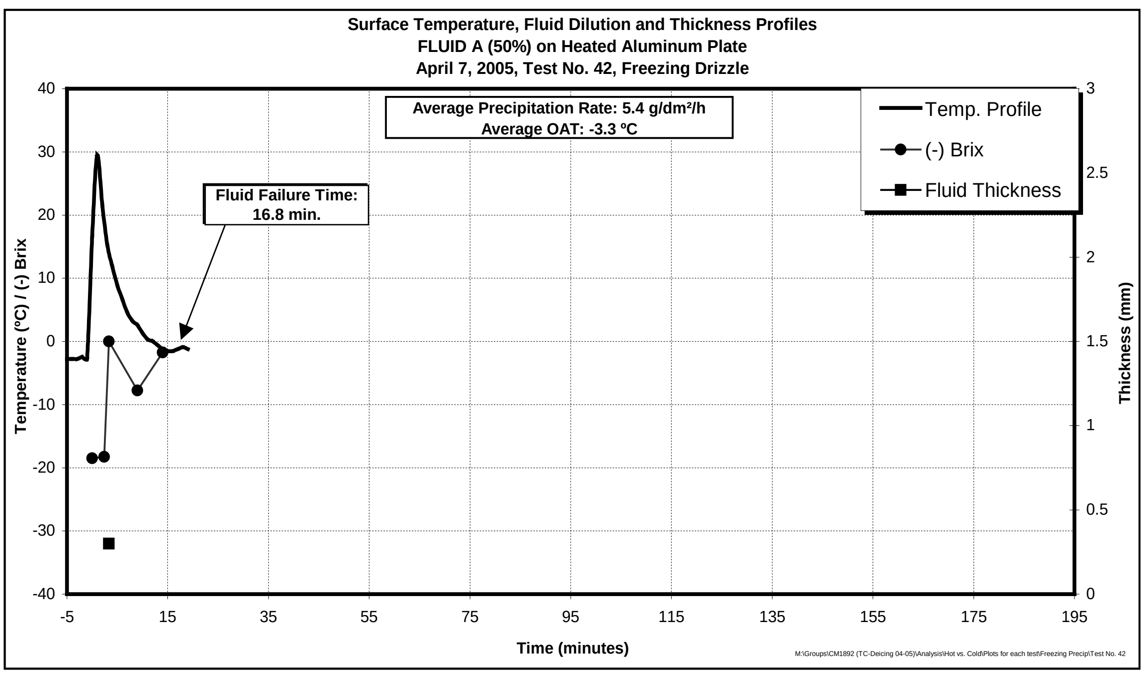

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Aluminum Plate
April 6, 2005, Test No. 34, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
10.5 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 34

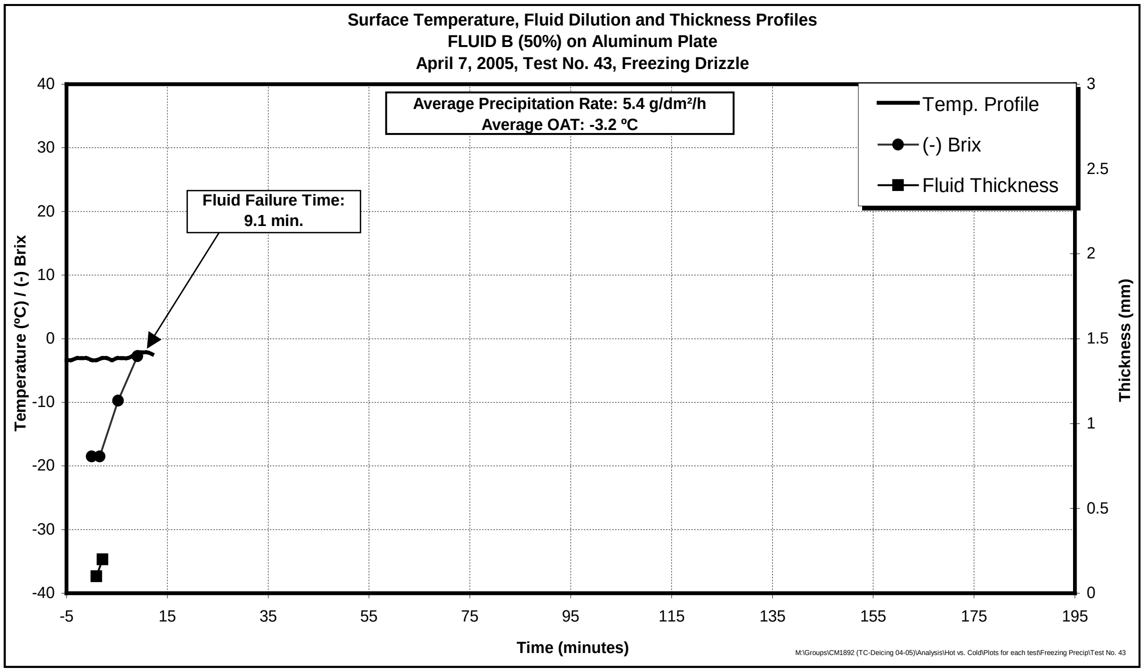

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Heated Aluminum Plate
April 6, 2005, Test No. 35, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.2 ºC
Fluid Failure Time:
13.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 35

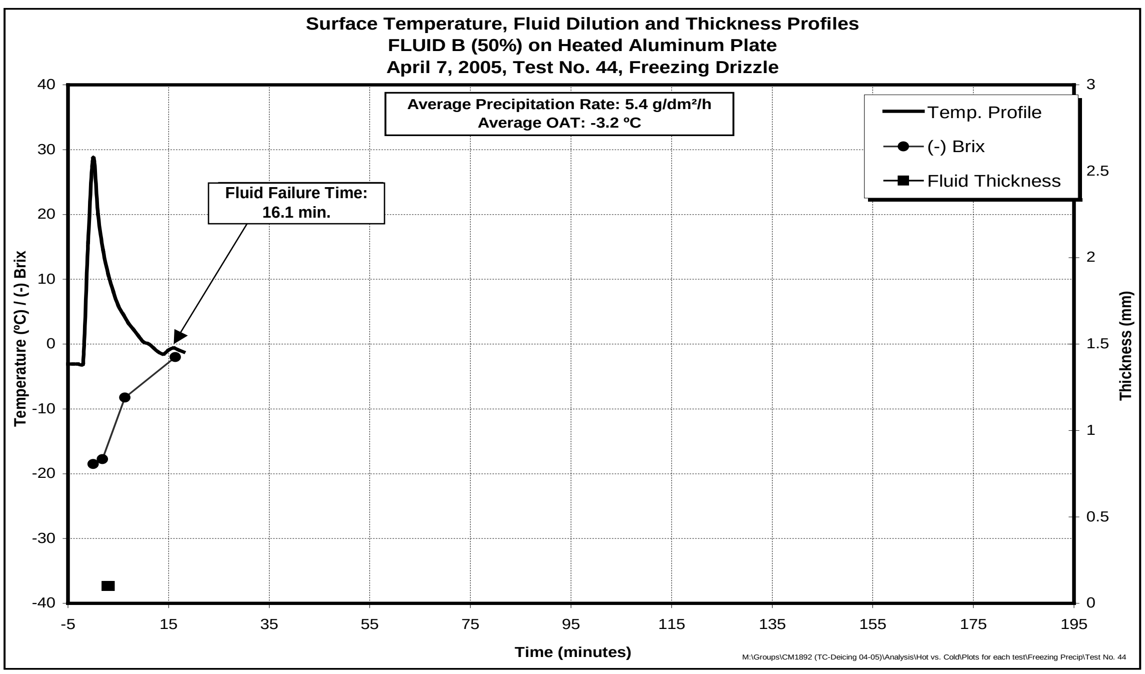

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Aluminum Plate
April 6, 2005, Test No. 36, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
32.5 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 36

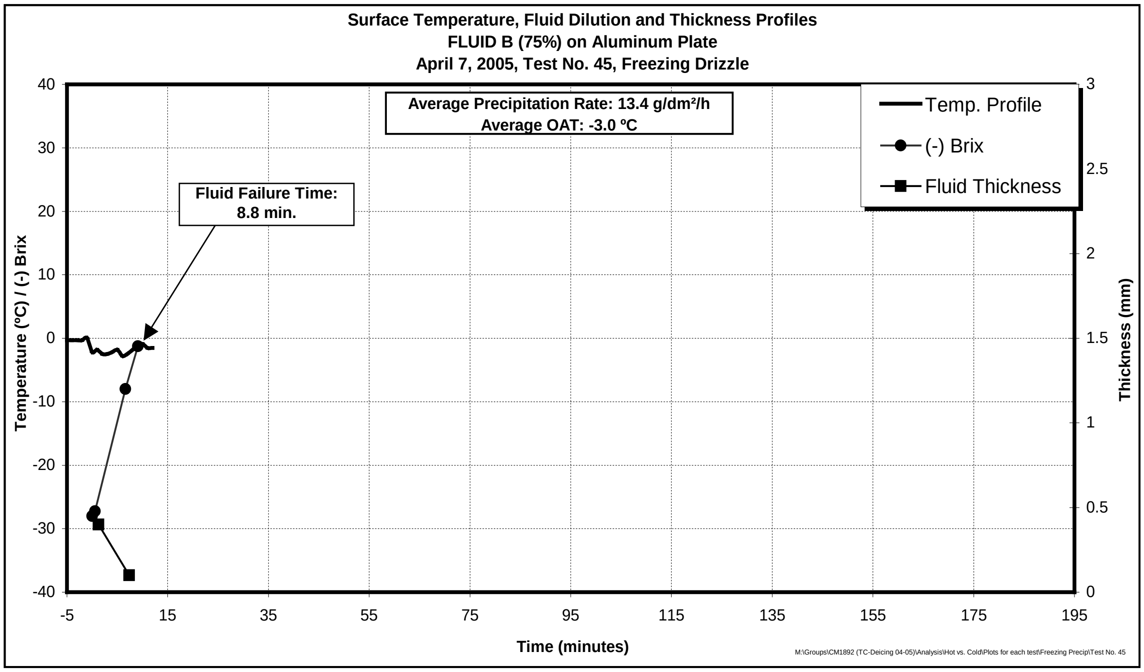

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Heated Aluminum Plate
April 6, 2005, Test No. 37, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
22.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 37

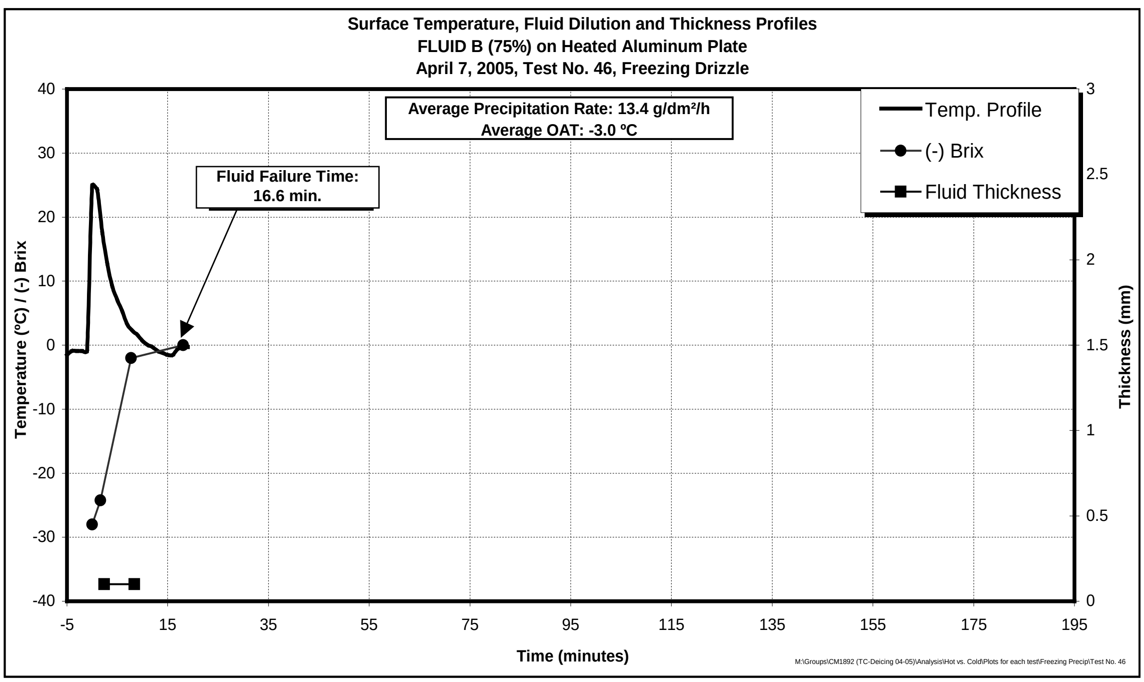

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Aluminum Plate
April 7, 2005, Test No. 41, Freezing Drizzle
Average Precipitation Rate: 5.4 g/dm²/h
Average OAT: -3.3 ºC
Fluid Failure Time:
11.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 41

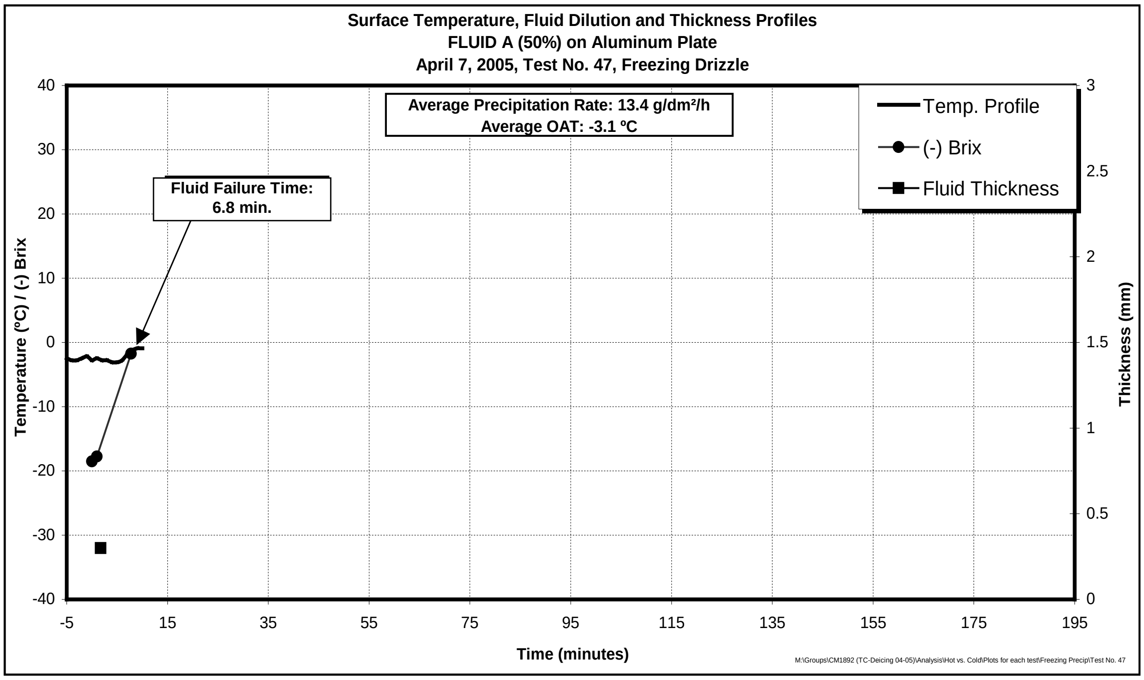

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Heated Aluminum Plate
April 7, 2005, Test No. 42, Freezing Drizzle
Average Precipitation Rate: 5.4 g/dm²/h
Average OAT: -3.3 ºC
Fluid Failure Time:
16.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 42

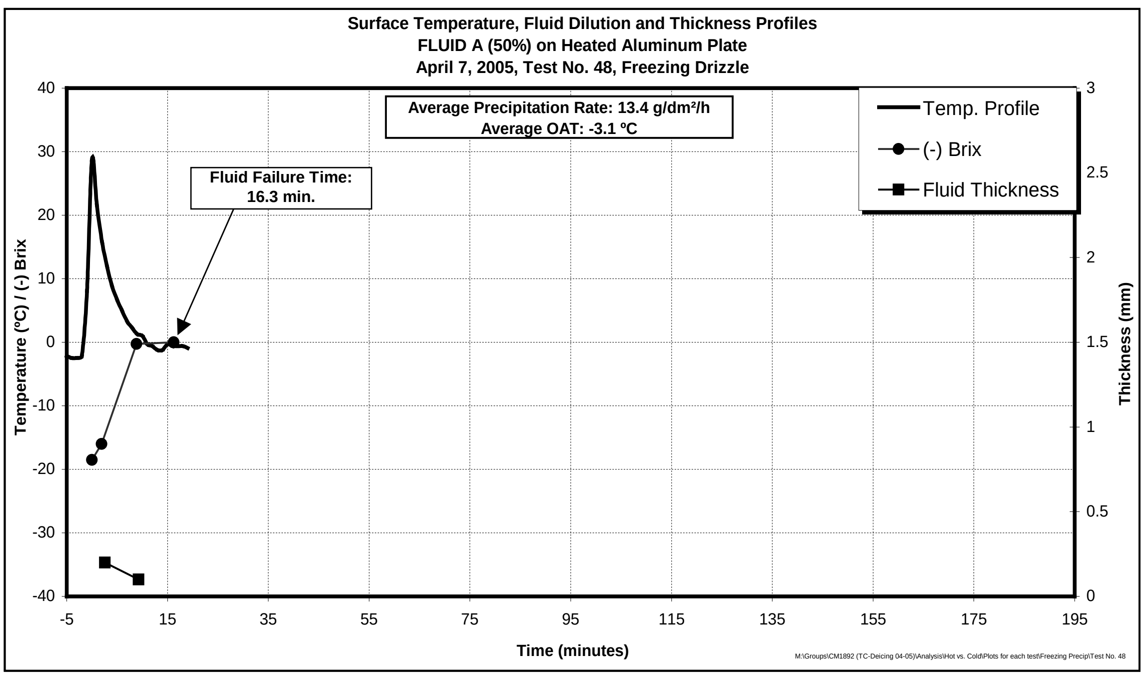

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (50%) on Aluminum Plate
April 7, 2005, Test No. 43, Freezing Drizzle
Average Precipitation Rate: 5.4 g/dm²/h
Average OAT: -3.2 ºC
Fluid Failure Time:
9.1 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

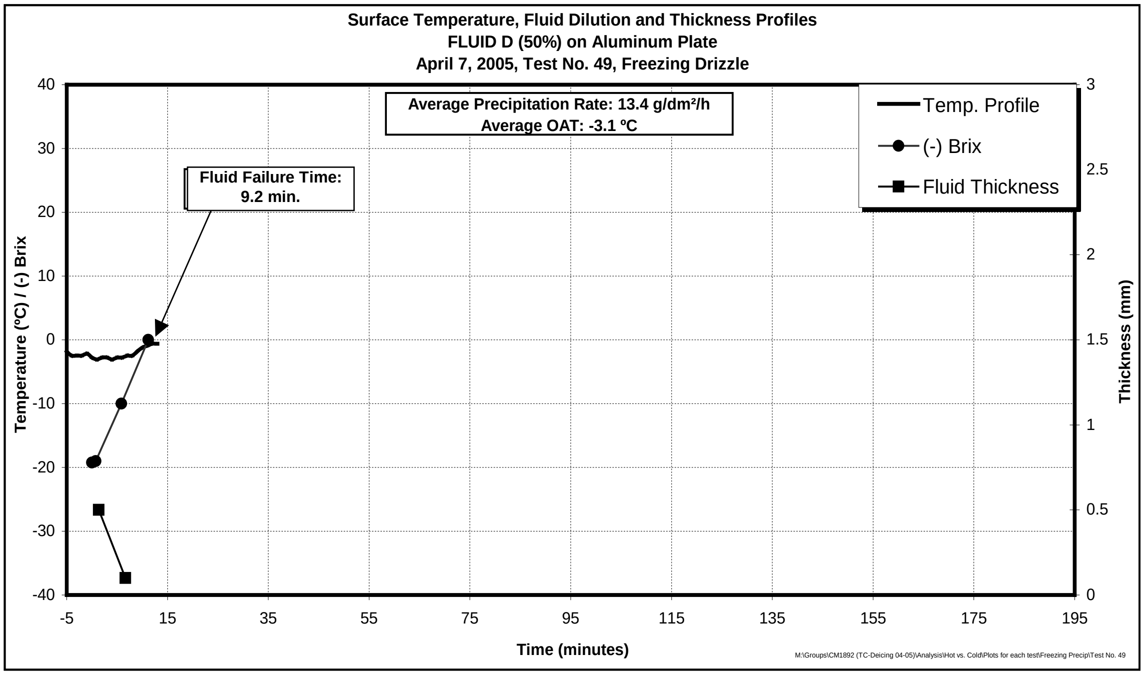

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (50%) on Heated Aluminum Plate
April 7, 2005, Test No. 44, Freezing Drizzle
Average Precipitation Rate: 5.4 g/dm²/h
Average OAT: -3.2 ºC
Fluid Failure Time:
16.1 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

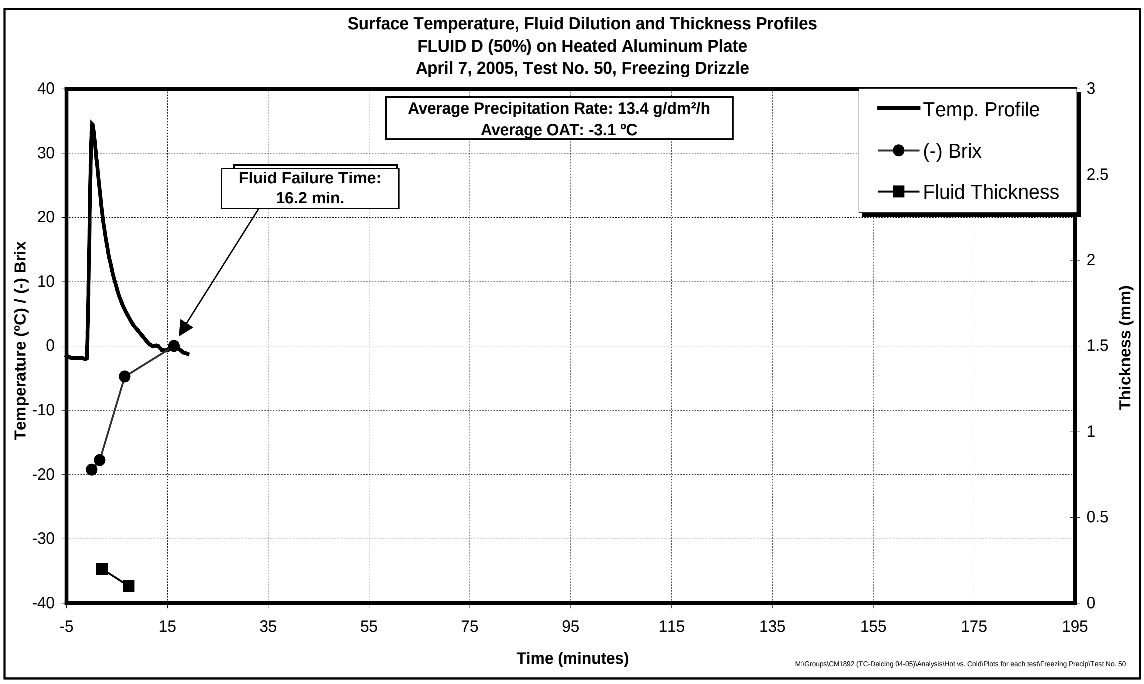

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
April 7, 2005, Test No. 45, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.0 ºC
Fluid Failure Time:
8.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Heated Aluminum Plate
April 7, 2005, Test No. 46, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.0 ºC
Fluid Failure Time:
16.6 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Aluminum Plate
April 7, 2005, Test No. 47, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
6.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Heated Aluminum Plate
April 7, 2005, Test No. 48, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
16.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (50%) on Aluminum Plate
April 7, 2005, Test No. 49, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
9.2 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 49


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (50%) on Heated Aluminum Plate
April 7, 2005, Test No. 50, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.1 ºC
Fluid Failure Time:
16.2 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Freezing Precip\Test No. 50